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Forest Health on National Forest Lands in the Blue Mountains 1990-1996: Insects and Diseases

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Agriculture

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Northwest
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**Blue Mountains Pest
Management Zone**

**Wallowa-Whitman
National Forest**

BMZ-96-12
May 1, 1996

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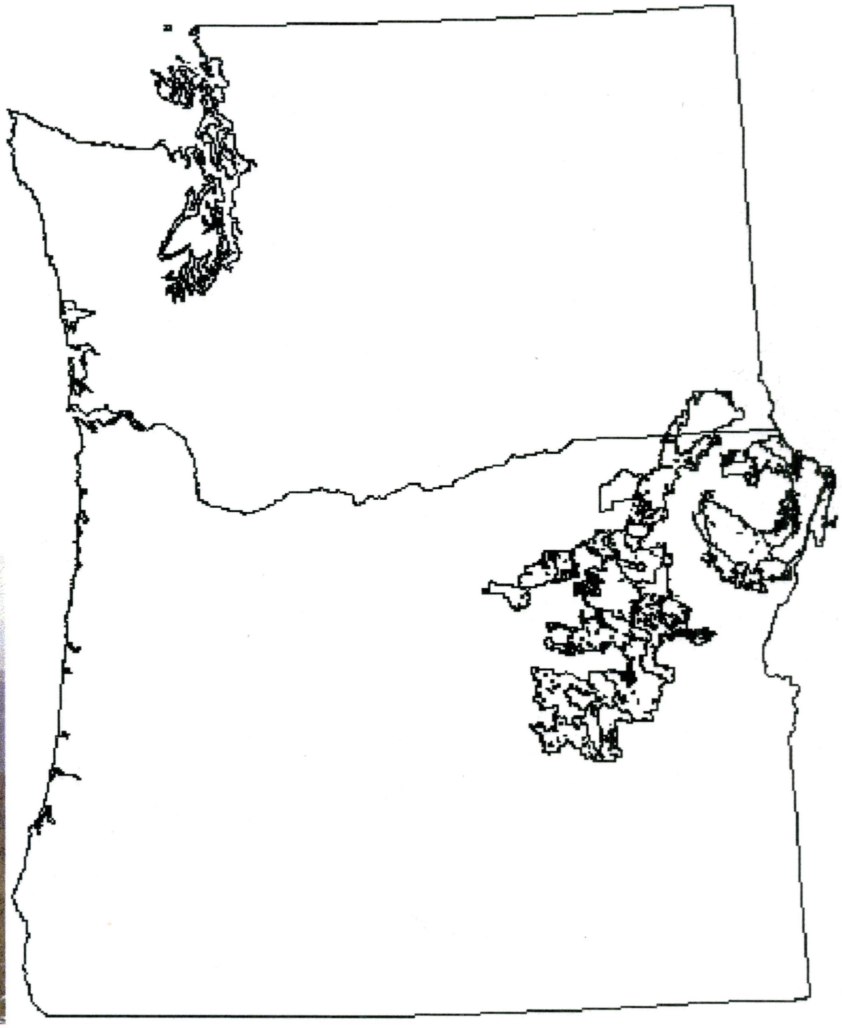

Caring for the Land and Serving People

Forest Health On National Forest Lands In The Blue Mountains 1990-1996: Insects And Diseases

Donald W. Scott, Zone Entomologist
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Blue Mountains Pest Management Zone
Wallowa-Whitman National Forest
La Grande, Oregon 97850

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ABSTRACT

Current insect and disease conditions, and recent insect infestation trends based on aerial insect detection surveys from 1990 through 1995, are reported in this document. Current conditions are also compared and contrasted with conditions that existed in 1991 when the Forest Health Report was first issued (see Gast et al. 1991). Discussions of insect and disease conditions and trends specifically cover the National Forest administered lands within the Blue Mountains Pest Management Zone, including the Malheur, Umatilla, and Wallowa-Whitman National Forests. Though this report addresses National Forest lands, with specific references to Ranger Districts or areas on Ranger Districts within a National Forest boundary, the general trends reported apply to a large extent to BIA, BLM, State, and private forest lands that are within or adjacent to the three National Forests, as well.

Insect populations fluctuate widely most of the time over any given area on any given year. They may reach outbreak levels, and may remain at outbreak levels for several years when conditions are favorable for insect increase, rapid development, and high survival. Several major insects were in outbreak during the preparation of the Forest Health Report. Some of these outbreak populations of insects have either collapsed entirely, or have declined and are presently fluctuating at much lower levels than previously. For example, after 13 years of defoliation of grand and white firs, and Douglas-firs in mixed conifer stands over the Blue Mountains region, populations of western spruce budworm have finally collapsed. Similarly, residual areas experiencing Douglas-fir tussock moth outbreaks of the past several years are now collapsed and are not expected to cause any further visible defoliation until the next outbreak, perhaps sometime around the year 2000.

Spruce beetle populations have also generally collapsed after more than a decade of killing spruce of nearly all sizes throughout the northern half of the Wallowa-Whitman NF. Other bark beetle populations associated with true firs and Douglas-firs are mostly in decline, while pine-associated bark beetles increased throughout the Blue Mountains over the last 4 or 5 years. Drought-stress and overstocking are believed to be the major factors driving the increase in populations of these beetles. Notable activity by Douglas-fir beetle in the early spring of 1994 in portions of the La Grande Ranger District and North Fork of the John Day Ranger District suggest that populations of beetles were still maintaining high levels within, and adjacent to, stands of trees severely defoliated by spruce budworm. Beetle-attacked trees that faded over the winter were not identifiable when the aerial survey was flown the previous summer. Consequently, some survey data for this insect may have underestimated extent of infestations on these Districts during certain years. Douglas-fir beetles have declined to lower levels the last several years, and are expected to fluctuate at about present levels in certain stands for a few more years in portions of the Blue Mountains defoliated by budworm.

All the significant tree diseases in the Blue Mountains do not have the dramatic population cycles characteristic of forest insects. However, in almost all cases diseases are increasing in occurrence and severity due to gradual changes in species mix, stand structure and certain types of disturbances that make stands increasingly susceptible to various disease infestations.

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INTRODUCTION

Historic and current conditions of insects and diseases affecting forest trees in the Blue Mountains were last discussed in detail as part of the Forest Health Report of 1991 (cf. Gast et al. 1991). Insect and disease conditions were updated for the period 1990 through 1993 in the report by Scott and Schmitt (1994). Since the Forest Health Report of 1991 was issued, several other efforts have expanded on that effort, and have analyzed historic and existing conditions on an ecosystem, and watershed basis (cf. Caraher et al. 1992; Everett et al. 1993; O'Laughlin et al. 1993; Schmidt et al. 1993; Johnson et al. 1995; Jaindl and Quigley 1996; and various others). Most notable among these and pertinent to the Blue Mountains, is the Eastside Forest Ecosystem Health Assessment, also known as "The Everett Report" (see Everett et al. 1993). This report encompassed not only the Blue Mountains, but all of the forested area within the states of Oregon and Washington from the crest of the Cascade Mountain Range to the eastern borders of each state. This report was produced in response to the request by then Speaker of the House of Representatives, Tom Foley, and Senator Mark Hatfield for a scientific evaluation of the effects of Forest Service management practices on the sustainability of eastern Oregon and Washington ecosystems.

At about the same time as the release of the Eastside Forest Ecosystem Health Assessment report, President Clinton released to the nation (July, 1993) the "Forest Plan for a Sustainable Economy and Sustainable Environment." This was part of a plan for implementing ecosystem management in the Pacific Northwest. Within this vehicle he directed the various federal resource management agencies to focus on the health of forest ecosystems east of the Cascades. Thus, another study was soon to be born.

Soon after the release of President Clinton's Forest Plan, the U. S. Department of Agriculture announced that the Forest Service would begin to develop a new management strategy for National Forests in eastern Oregon and Washington. In January of 1994 an interagency charter was signed by the U. S. Forest Service and the Bureau of Land Management to initiate a process aimed at developing a scientifically sound, ecosystem-based strategy for eastern Oregon and eastern Washington. Formerly called the "Eastside Ecosystem Management Project," the geographic scope of it's area of study was expanded to encompass lands within other western states whose watersheds contributed to the Columbia River drainage system. Hence, this enlarged project focusing on ecosystem management in the Pacific Northwest, now became called the "Interior Columbia River Basin Ecosystem Management Project." As the project nears completion of its work, the project is beginning to publish some of its findings in reports such as, Search For A Solution: Sustaining The Land, People, And Economy Of The Blue Mountains" (see Jaindl and Quigley 1996). Among other things, this report examines the complexity of insect and disease factors and interactions with other agents that have been partially responsible for the decline in the health of forest ecosystems within the Blue Mountains of northeastern Oregon and southeastern Washington.

Unlike the broader scope of the studies and reports mentioned above, we focus our report primarily on the insect and disease conditions, and their influence on the forest environment of the Blue Mountains. We discuss and update trends of insects and diseases on Forest Service-administered lands of the Blue Mountains of northeastern Oregon and southeastern Washington. Specifically, our report covers forested lands of the Malheur, Umatilla, and Wallowa-Whitman National Forests. The coverage of insect and disease conditions on these National Forests is made possible by the continuous insect infestation data provided by the annual cooperative aerial insect detection survey conducted by the Pacific Northwest Region of the Forest Service and the states of Oregon and Washington, and also by the unique opportunities afforded by our positions as Zone Pest Management Specialists in northeast Oregon and southeast Washington. Our annual distribution of work to meet the requests of our "clients" on Ranger Districts, Forest headquarters, and Bureau of Indian Affairs and Bureau of Land Management offices enables us to visit large portions of forested lands within the Blue Mountains. Much of the discussion in this report is based on our personal observations and experience in dealing with insect and disease infestations over the previous six years. Accordingly, this report updates insect and disease information for the period 1990 through 1995, providing a broad 6-year "snapshot" of insect and disease conditions and trends in the Blue Mountains as they exist today, compared with conditions in 1991 when the Forest Health Report was completed. References to "the three National Forests" in this report refer collectively to the Malheur, Umatilla, and Wallowa-Whitman National Forests.

Environmental Influences, Insects and Diseases, and Ecosystem Processes

Trees are affected by a variety of biotic and abiotic influences during their lifetime. Windstorms, fire, and drought are the most influential weather- or environmental-related factors of tree and conifer community health. Predisposition of trees by abiotic influences oftentimes encourage interactions with biotic factors (e.g., insects and diseases). For example, fire-weakened trees are very often attacked by insects that seize upon opportunities to use an abundant resource that has suddenly become available for breeding habitat. Under these conditions, populations may build up and invade healthy green timber in surrounding stands. Trees may be weakened by abiotic influences such as heavy snow and ice storms resulting in top-breakage, extreme moisture stress on xeric sites, lightning-ignited fires, or windstorms resulting in blowdown. It is common for certain bark beetles to capitalize on windthrow, breeding in the downed trees and then invading nearby healthy trees when the blowdown hosts have been depleted. Recent drought conditions from 1985 through 1992, and windstorms in 1981, 1991, 1992, 1994, and 1995 have contributed to the increased activity of several major bark beetle species in portions of the Blue Mountains.

Insects and diseases have traditionally been considered "pests" in that "control" was aimed at reducing their effects on their hosts, or their numbers to as low as possible. In many situations, this philosophy is still applicable, as with non-native insects and diseases, like the gypsy moth (*Lymantria dispar*) and white pine blister rust (*Cronartium ribicola*), which were inadvertently introduced into the United States from other continents. Other situations where native insect populations rapidly build in response to a major forest disturbance and threaten the loss of a resource, or place other non-timber resources at high risk to damage or loss, also demand prompt action to suppress populations before they reach damaging levels. High risk to fisheries from siltation and elevated stream temperatures following stand-replacement fires along riparian habitats where the Engelmann spruce has been depleted during a spruce beetle (*Dendroctonus rufipennis*) outbreak is a relevant example of the latter.

The interrelationship of insects and diseases with other ecosystem components is considerably complex. These diverse relationships compound the management of insect and disease populations in an ecosystem management approach, over the more simplified approaches used in the past. Traditional insect control usually amounted to treating infestations with chemical insecticides, sometimes with little regard to the direct or indirect effects on the ecosystem. Over the years Forest Service policy, guided by new research, has changed to the present Integrated Pest Management (IPM) approach. This in turn is modified by ecosystem management.

Ecosystem management often strives to maintain an endemic level of insects and diseases consistent with their historic levels of activity that is within the natural range of variability for those plant communities. To attempt to eliminate an organism that is integral, and contributes to the ecosystem's function or processes would not only be disruptive to the system, but might also be disastrous to certain taxa within the ecosystem that depend on that organism. For example, bark-feeding and woodboring insects make up a good portion of the diet of certain avian species such as the black-backed woodpecker, *Picoides arcticus* (Beal 1911; Bent 1939, 1964; Blackford 1955; Crockett and Hansley 1978; Goggans et al. 1987; Wickman 1965). Hypothetical elimination of these arthropods over a large habitat area might seriously threaten populations of those species dependent on these food sources. On the other hand, while insect- and disease-created snags and down trees, and trees with decay and witches' brooms, etc., provide habitat for a variety of forest-dwelling flora and fauna including microbes, fungi, invertebrates, small animals, and cavity-nesting and other birds, the levels of these insect- and disease-contributed components may sometimes far exceed levels that would constitute a healthy ecosystem. One of the driving forces behind the recent interest in forest and ecosystem health has been the highly visible and widespread occurrence of insects, diseases, and wildland fires that have damaged watersheds all across the Blue Mountains. We speculate that it has become increasingly more common over the past several decades for the levels of insect- and disease-created habitats to far exceed what was provided under pre-settlement conditions. Since stand conditions have changed such that insects and diseases are now much more active, commonplace, and widespread, and are creating excessive influences we classify as "damage," under these conditions we consider these organisms to be pests.

Insect and disease management options and levels will obviously vary depending upon ecosystem management objectives and the nature of the organism, its perceived status at a given point in time, and its ultimate role in ecosystem management, given those management objectives. We will not attempt to provide specific insect and disease management prescriptions, as those have been addressed elsewhere (see Gast et al. 1991). Discussions will be limited to current trends and conditions of insects and diseases. We also discuss certain factors affecting the condition of trees, stands, and forests within the Blue Mountains, in relationship to Historic Range of Variability, and why some insects and diseases will continue to be problematic in the future.

4

RECENT TRENDS IN INSECT POPULATIONS

DEFOLIATORS

Western Spruce Budworm (*Choristoneura occidentalis* Freeman)

The western spruce budworm (*Choristoneura occidentalis*) is considered to be the most destructive forest defoliator in Western North America (Furniss and Carolin 1977). Immature stages of the budworm feed on a wide range of conifer hosts (Gast et al. 1991), but in the Blue Mountains grand fir, *Abies grandis* (Dougl. ex D. Don) Lindl.), white fir, *A. concolor*, (Gord. and Glend.) Lindl.ex Hildebr., and Douglas-fir, *Pseudotsuga menziesii* (Mirb.) Franco, are the host tree species most seriously damaged by budworm. Budworm larval feeding on current year foliage causes foliage to turn red by midsummer (Fig. 1). After several years of heavy loss of foliage, budworm defoliation can lead to tree mortality mostly in the suppressed understory trees, and top-kill in the larger trees. Trees weakened by budworm defoliation are often predisposed to attack by bark beetles.

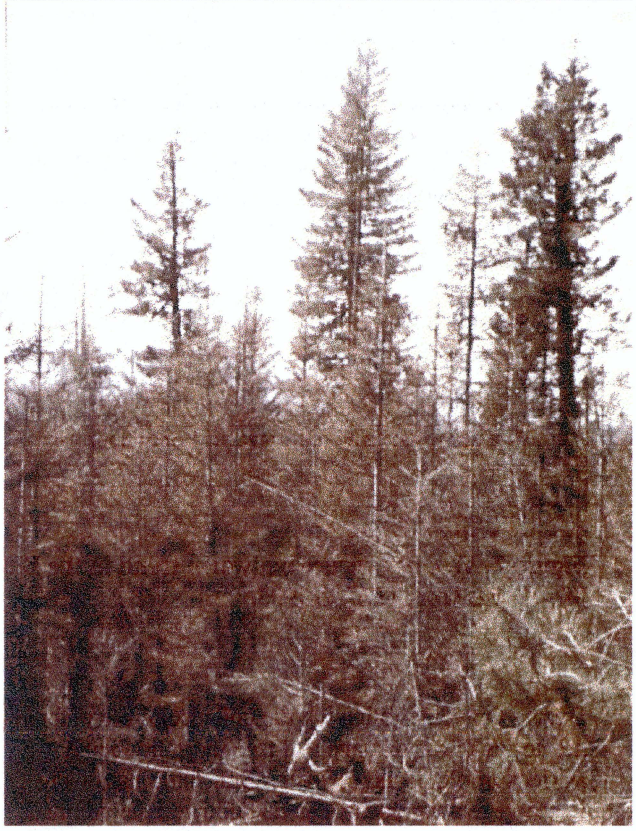


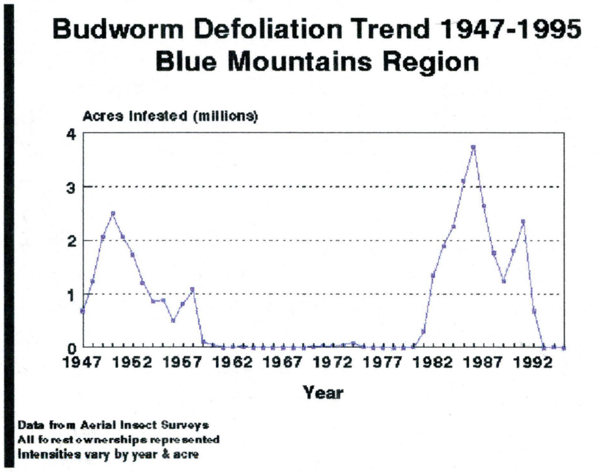
Figure 1. Grand fir and Douglas-fir defoliated by western spruce budworm.

Trends and Population Levels

The most recent outbreak to occur in the Blue Mountains began in 1980 (Gast et al. 1991). Budworm populations increased rapidly in stands containing host trees throughout the Blue Mountains from 1980 through 1986. Following a brief decline from 1987 through 1989, populations resurged for a couple of years before collapsing completely in 1993 (Fig. 2). Little or no budworm defoliation has been observed following the collapse in 1993 to the present. Budworm population trends were similar on all three National Forests over the past six years (Fig. 3). The termination of the outbreak was widespread and uniform throughout the Blue Mountains.

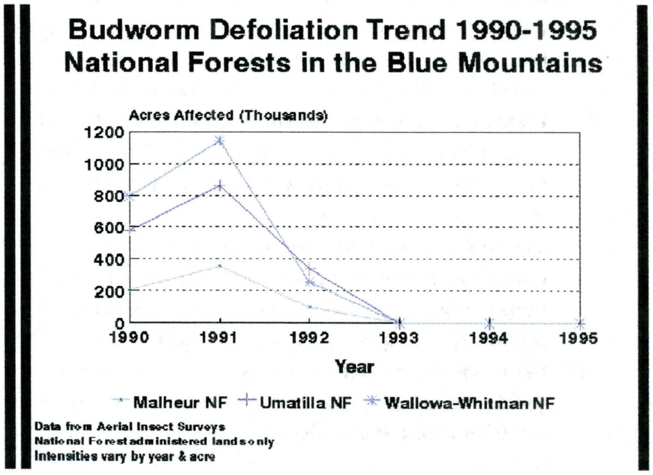
The two major outbreaks of budworm in the latter half of this century were similar in both outbreak pattern and duration (see Fig. 2). Curiously, both outbreaks showed a bimodal pattern, reaching two distinct outbreak peaks before finally collapsing. Also, each outbreak lasted 13 years: The recent outbreak occurred from 1980 through 1993; the previous major outbreak occurred from 1946 through 1959 (Fellin 1985).

When forest health conditions were discussed in the report by Gast et al. (1991), budworm populations were still very high. In 1991 over 350,000 acres of budworm defoliation were recorded for the Malheur National Forest, over 860,000 acres were recorded for the Umatilla National Forest, and over 1,140,000 acres were defoliated on the Wallowa-Whitman National Forest that year. Many of the areas in the Blue Mountains defoliated by budworm appeared as in figure 1, in 1991. Other areas were not as severely defoliated, and trees appeared to have a good to excellent chance of recovering from the budworm damage. Today, most trees that were not severely weakened by budworm defoliation and drought stress have been gradually recovering from defoliation by replacing foliage with each year's production of new needles. Some of these trees are beginning to look relatively healthy again, while others still appear severely damaged, and may not survive (Fig. 4). Though most of the trees are recovering, probably hundreds of thousands of other host trees across the Blue Mountains, mostly in the suppressed understory and overtopped tree classes, have succumbed to the combination of defoliation, drought stress, and overcrowding. Still other larger trees survived the defoliation and drought, and began to recover, only to be killed by bark beetles that had built up during the outbreak. Bark beetles have been attracted to these trees that were still in a somewhat weakened state following the outbreak.



Data from Aerial Insect Surveys
All forest ownerships represented
Intensities vary by year & acre

Figure 2. Western spruce budworm trend in the Blue Mountains from 1947 to 1995.



Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 3. Western spruce budworm trend on National Forests in the Blue Mountains from 1990 to 1995.

During the years following the collapse of the outbreak, memories of the damage and tree mortality begin to fade as trees refoliate and recover. Still, little has changed of the vegetation conditions that allowed the outbreak to encompass such a broad area of the landscape, and cause a significant amount of tree mortality, radial- and height-growth loss, and creation of dead standing ladder fuels. The budworm outbreak was promoted by the proliferation of mixed conifer stands of overstocked, multistoried, shade-tolerant true fir- and Douglas-fir-dominated species. These stands developed over many decades, mostly in response to the diminishing role of natural, low-intensity, high-frequency surface fires, but also through selective harvesting of seral pines and larch (Agee 1993; Anderson et al. 1987; Carlson and Wulf 1989; Gast et al. 1991; Schmidt 1985; Swetnam and Lynch 1989; Wickman 1992; Wulf and Cates 1987).

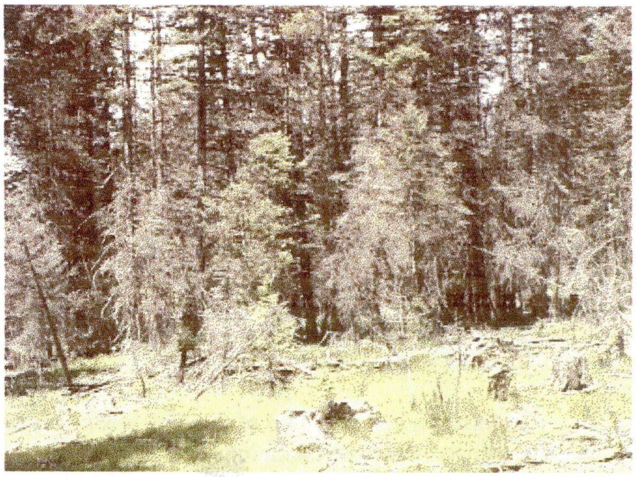


Figure 4. Foliage recovery on grand fir after collapse of budworm outbreak.

Besides an abundance of favored habitat for budworm, a seven-year drought provided favorable climatic conditions in which the budworm could achieve rapid larval development and high survival rates. Assuming no changes in food quality, studies have shown that insects will grow faster and larger, suffer less mortality, and lay more eggs per unit of ingested food, when provided optimal temperature regimes (Mattson and Haack 1987). The same can be said for the major natural enemies of budworm, but their population increases usually lag behind that of their prey or host species. These factors, coupled with relatively low initial levels of natural enemies to help keep populations of budworm in check, enabled budworm to rapidly increase in numbers and develop to injurious levels in stands.

Effects of Budworm Outbreaks on Forest Resources

Over the course of the outbreak, millions of acres of white fir, grand fir, and Douglas-fir dominated stands, along with other minor host species were defoliated, top-killed, or killed outright by budworm (tree mortality was mostly in the understory). In stands where trees survived budworm defoliation, trees now show substantial radial growth reductions. Host trees are only now beginning to produce good seed crops again, after years of little seed production due to the destruction by budworm of male strobili, and developing seed cones. In addition, low starch reserves in heavily defoliated trees contributed to lack of seed crops since carbohydrates, especially reserve starch, and certain amino acids are required for cone-bud development (Allen and Owens 1972). Many other trees have begun to form double or multiple tops because of leader-kill by budworm. In time, some of these trees may manifest major bole deformities.

While these impacts are directly attributed to budworm, and are generally associated with timber resource concerns, many other resource values are also influenced to one degree or another--some positively; others negatively. For example, budworm-caused defoliation and tree mortality affects many resource concerns including: (1) quality of scenic vistas and recreation areas; (2) wildlife habitat and cover; (3) streamside shading; (4) stream habitats; (5) nutrient cycling; (6) old-growth and riparian areas; (7) watershed dynamics (e.g., water yields, interception of precipitation, etc.); and of course, (8) forest fuels condition which influences the risk of wildfire (Gast et al. 1991).

Implications of Budworm and Drought Weakened Trees for Other Insects

The severe weakening of budworm-defoliated trees while growing under moisture stress predisposed many stands to attack by various bark beetles. Significant buildups of populations of Douglas-fir beetles, *Dendroctonus pseudotsugae*, in Douglas-firs, and fir engravers, *Scolytus ventralis*, in grand and white firs have occurred in many places in the Blue Mountains. Defoliator outbreaks in mixed conifer stands are often followed by increased attacks by these bark beetles (Berryman 1973; Wickman 1958, 1963, 1978; Wright et al. 1984). Douglas-fir beetles have been largely responsible for killing the larger diameter trees in old-growth and riparian habitats such as on the north end of the Wallowa-Whitman. Similar stands on nearly every ranger district in the Blue Mountains with significant budworm defoliation have had outbreaks of Douglas-fir beetles, as well. The killing of pole-sized true firs by fir engravers that might have otherwise survived budworm defoliation is even more commonly seen scattered throughout the defoliated and drought-stressed stands of the three Forests. Populations of this bark beetle may be even more common than Douglas-fir beetles, even under endemic conditions, due to its close association with root-diseased trees (Hertert et al. 1975; Lane and Goheen 1979; Miller and Partridge 1974).

Tree Recovery and Prospects for Future Outbreaks

Refoliation and retention of the new foliage on trees during the spring of 1993 were the net result of the improved moisture conditions and relief of budworm defoliation pressure. Many trees that were nearly dead--stripped of nearly every needle--began displaying a flush of new foliage during the spring of 1993 from latent buds produced the previous year. By 1995, many defoliated trees had made dramatic recovery. Still, survival of many of these trees is questionable, and will be predicated on the degree to which the trees have exhausted energy reserves, can withstand additional seasons of drought stress should it occur, and continue to be exposed to secondary insects and pathogens over the next few years.

Although budworms are a part of the natural forest ecosystem, and historic outbreaks--even in centuries past--have been carefully documented for portions of the Blue Mountains by Swetnam et al. (1995), modern outbreaks recorded since the turn of this century appear to have increased in frequency and severity over earlier times. To a large extent this has occurred as a result of increases in true fir and Douglas-fir in predominantly dry pine communities, over historic levels. To date, little changes in vegetation patterns have occurred that would make these stands any more resistant to budworm; but this would be expected in the short time since publication of the strategies in 1991 Forest Health Report for the Blue Mountains. We consider outbreaks of defoliators like the recent budworm outbreak in the Blue Mountains to be outside the Historic Range of Variability for this insect. We also know that future outbreaks of budworm will occur--perhaps not for another couple of decades. While we cannot predict with certainty when the next outbreak will occur, we can at least be sure that the implications of not managing vegetation in the Blue Mountains to return stands to the plant assemblages, stocking levels, and structural components of earlier times, will be the repeat of another widespread budworm outbreak of equal or greater destruction to this last outbreak.

Recent Budworm Population Suppression Efforts

Options for managing outbreaks of defoliators like budworm are somewhat limited. Intervention with insecticide treatments to suppress populations or reduce subsequent damage is oftentimes the decision that is made during the analysis of outbreaks. Biological evaluations by entomologists are used to determine population levels and discuss options for mitigating an infestation that causes unacceptable damage to forests and forest resources. Such an analysis of results of sampling of budworm populations in 1991 on portions of the Walla Walla RD, La Grande RD, and Wallowa Valley RD found that population densities in 1992 would be high enough to cause moderate to severe defoliation of host trees (Scott 1991).

A joint environmental analysis conducted during 1991 by personnel from the Umatilla NF and the Wallowa-Whitman NF found that the affected resources on the analyzed areas would benefit from treatment with insecticides. An Environmental Assessment was subsequently signed by the Forest Supervisors of both Forests, selecting treatment of seven areas with the microbial insecticide *Bacillus thuringiensis* to reduce budworm populations to levels that would be less damaging. Accordingly, the Forests corporately treated 116,344 acres on the Walla Walla and La Grande Ranger Districts (Hadfield 1992), and 70,222 acres on the Wallowa Valley Ranger Districts (Howes and Wallesz 1993).

While populations and subsequent damage were reduced in the areas of treatment, results were short-lived. In examining the effects of insecticide treatments on subsequent defoliation by spruce budworm in the Pacific Northwest Region during the years 1982-1992, Sheehan (1996) concluded that various treatments reduced the extent of subsequent defoliation for at most one year. Differences between treated and adjacent untreated areas were very slight or undetectable in either extent or severity of defoliation. Hence, strategies for managing budworm populations that address the condition of a stand's susceptibility and its vulnerability to damage by budworm would offer much greater promise of long-term population management, if done over large areas. Strategies and prescriptions offered by Gast et al. (1991) are still valid today; but few have been implemented on the broader landscape that is in need of treatment.

Douglas-fir Tussock Moth (*Orgyia pseudotsugata* (McDunnough))

Douglas-fir tussock moth (*Orgyia pseudotsugata*) (Fig. 5) is a major defoliator of grand fir, white fir, and Douglas-fir in the interior forests of western North America. In the Blue Mountains, these hosts are severely defoliated and often killed when tussock moth outbreaks erupt.

Tussock moth larvae feed initially on new foliage, but unlike western spruce budworm, tussock moth also feeds on older foliage from previous years as the larvae mature. This feeding pattern defoliates trees much more quickly than that of budworm; hence, trees may be stripped of every needle by this insect in one season, sometimes killing the tree. In contrast, budworm usually requires several years of heavy defoliation to kill trees.

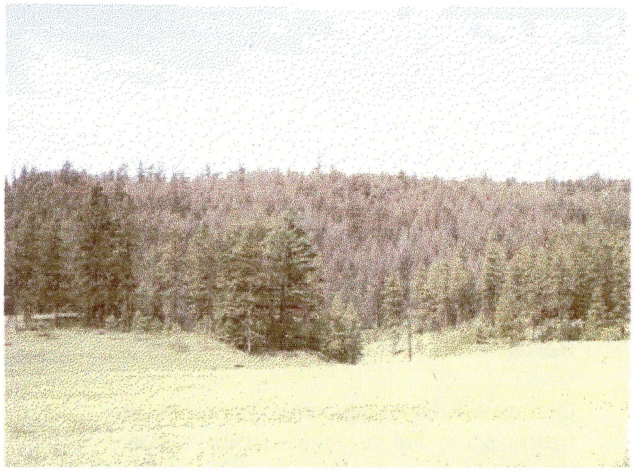


Figure 5. Defoliation of grand fir and Douglas-fir by Douglas-fir tussock moth.

Trees being defoliated by tussock moth become devoid of needles from the top downward due to the behavior of the insect congregating and feeding at the top of the tree first. As trees continue to be stripped of needles by the insect, they begin to take on a gray appearance as branches and boles are exposed (Fig. 5). Mortality usually is patchy, occurring in groups of trees rather than across wide continuous areas.

Tussock moth outbreaks usually erupt quickly, last 3 or 4 years, and then decline rapidly. Outbreaks tend to be cyclical, occurring on average approximately every 8-9 years in somewhat synchronous fashion across wide areas (Clendenen et al. 1978; Shepherd et al. 1988). Tussock moth populations are monitored annually by pheromone trapping in an "Early Warning Detection" program (Daterman et al. 1979). Forest Service offices, and other federal and state agencies participate in this annual detection program for tussock moth.

Trends and Population Levels

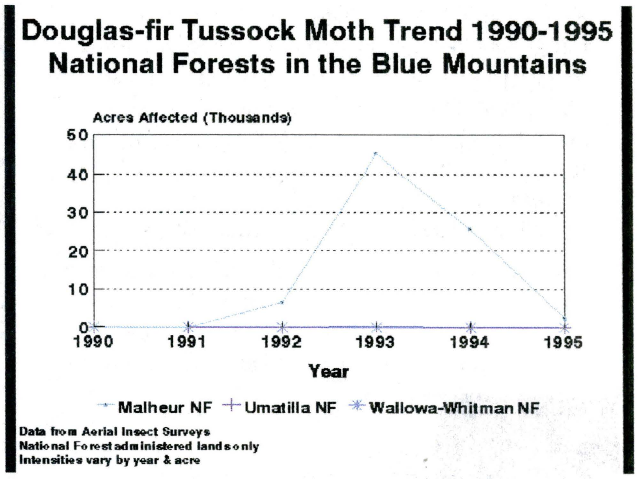
Douglas-fir tussock moth populations increased rapidly on the Wallowa-Whitman NF from suboutbreak levels first discovered on the Pine RD in 1989 (Scott and Mason 1989). Unfortunately, the occurrence of these populations on the Pine and La Grande Ranger Districts, and the Hells Canyon National Recreation Area, could not be aerially mapped due to the presence of considerable budworm defoliation occurring simultaneously over much the same area as tussock moth.

During 1991, those populations on the Wallowa-Whitman that were analyzed and would benefit from treatment, were treated with the bacterial insecticide, *Bacillus thuringiensis*. A total of 116,064 acres were treated to reduce insect numbers

Lower crown sampling conducted on Ranger Districts throughout most of the Blue Mountains in 1991 found populations to be either low or very low, and remained so in subsequent years except for certain locations on the Malheur NF. Defoliation of white firs and Douglas-firs occurred in many stands on the Bear Valley RD (Malheur NF) near Fields Peak in 1991 and 1992. Though populations of tussock moth could be found over a larger area, the heaviest damage covered an area of approximately 140 acres. Some patches contained trees with defoliation ranging from roughly 40 to 70 percent. Subsequent tree mortality was very low. Several areas were sampled during 1992, but populations were already beginning to decline. High rates of pupal parasitization were noted during late-summer observations of the area in 1992. Larvae were also killed by parasitic wasps and by nucleopolyhedrosis virus (NPV). By the end of that season, populations had virtually collapsed over most of the area.

While the Fields Peak (Fields Creek)/Beaver Creek area was beginning to have increasing populations, populations at several other areas on the Burns RD were also beginning to build up; but this infestation covered a much broader area and included more locations than on the Bear Valley RD. The areas on the Burns RD included the Coffee Pot/Rattlesnake, Thompson Springs, and Gold Hill. These areas covered approximately 150,000 acres, though many of these areas apparently were not observed during the aerial detection survey (see Fig. 6). An additional 40,000-50,000 acres of tussock moth defoliation were mapped in during the annual aerial survey for insects during the late summer of 1993. Most of the latter area includes stands from south and southeast of Calamity Butte, north to Jump-off Joe Mountain. Lower crown sampling during 1992 of all areas except the latter areas mentioned, found relatively high rates of mortality of the pupal stage. Two of the areas (Coffee Pot/Rattlesnake and Thompson Springs had overall pupal mortality rates of 51 and 62 percent, respectively; the Gold Hill area had about 26 percent mortality in the pupal stage. Populations were expected to crash during 1993; however, larval sampling that summer found outbreak numbers of larvae to still be present in these areas. A visit to outbreak areas on the Burns RD during September of that same year found high levels of mortality from virus, parasitization, predation, and possibly starvation in some instances. The relatively high numbers of larval cadavers suspended from branches and leaders of many trees were particularly dramatic in depicting the action of the NPV on the population. Egg masses--the few that could be found--were brought back to the laboratory for rearing. All but one contained virus. Obviously this population was indeed crashing, but plans were to monitor these areas again in 1994 to confirm the population collapse.

Aerial detection survey in 1994 mapped 25,731 acres of tussock moth defoliation (Fig. 6), down considerably from previous years. By 1995, only 2,489 acres of defoliation could be detected over the areas of previous infestation. Clearly, the outbreak was over, and only a few small residual populations were left. We do not anticipate additional defoliation from tussock moth in 1996.



Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 6. Douglas-fir tussock moth trend on National Forests in the Blue Mountains from 1990 to 1995.

Like budworm, tussock moth is a native species to the forests of western North America. Populations will remain endemic for several more years before tussock moth erupts to outbreak levels again. The increase in host-type stands across the Blue Mountains over the past 80 years or more that fire suppression has been widely practiced, sets the stage for another widespread epidemic, perhaps similar to the 1970's tussock moth outbreak. It is difficult to say without more dendrochronological research in the Blue Mountains, but we strongly suspect that tussock moth outbreaks, particularly ones like the 1970's outbreak may exceed historic range of variability, both in extent of damage and intensity or severity to hosts.

BARK BEETLES

Spruce Beetle (*Dendroctonus rufipennis* (Kirby))

The spruce beetle (*Dendroctonus rufipennis*) (Fig. 7) is the most destructive insect on spruce in North America. Spruce beetle infests all species of *Picea* in North America (Schmid and Frye 1977), but only Engelmann spruce, *Picea engelmanni* (Perry) ex Engelm. occurs in the Blue Mountains. Engelmann spruce is the most important host for spruce beetle in the lower 48 states (Gast et al. 1991).

The insect produces populations that have life cycles varying from one to three years. Most infestations of spruce beetle requires two years to complete a life cycle at higher elevations and colder sites in the Blue Mountains, but one-year life cycle populations are also sometimes present. The one-year life cycle appears to be more common at lower elevations and warmer sites, though we offer no hard-and-fast rules on this.

Spruce beetles normally invade injured, windthrown, diseased and stressed trees as well as logging slash and cull logs and stumps (Gast et al. 1991). Nearly all major spruce beetle outbreaks have been traced to windthrow, logging debris following harvests, and other stand disturbances (Schmid and Frye 1977; Wygant and Lejeune 1967). Once spruce beetle colonize windthrow or other suitable habitat that is abundant, populations build up to such levels that beetles begin attacking healthy green spruce within nearby stands. Outbreaks, once started, are difficult to control. These infestations usually collapse after depleting the supply of spruce hosts in stands. The beetle kills all tree sizes down to about 6 to 8 inches, though it prefers trees larger than 18 inches d.b.h..

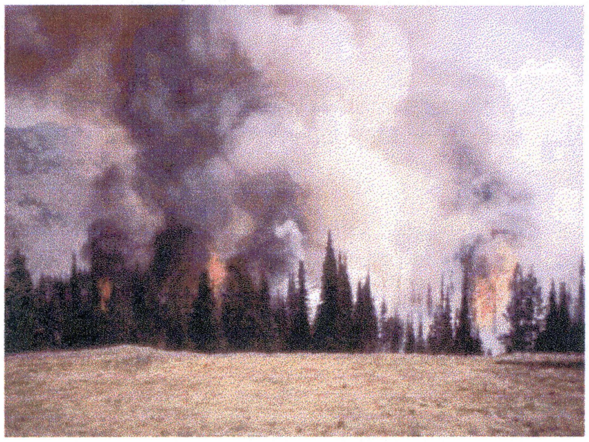


Figure 8. Recent Fires on the Wallowa-Whitman NF.

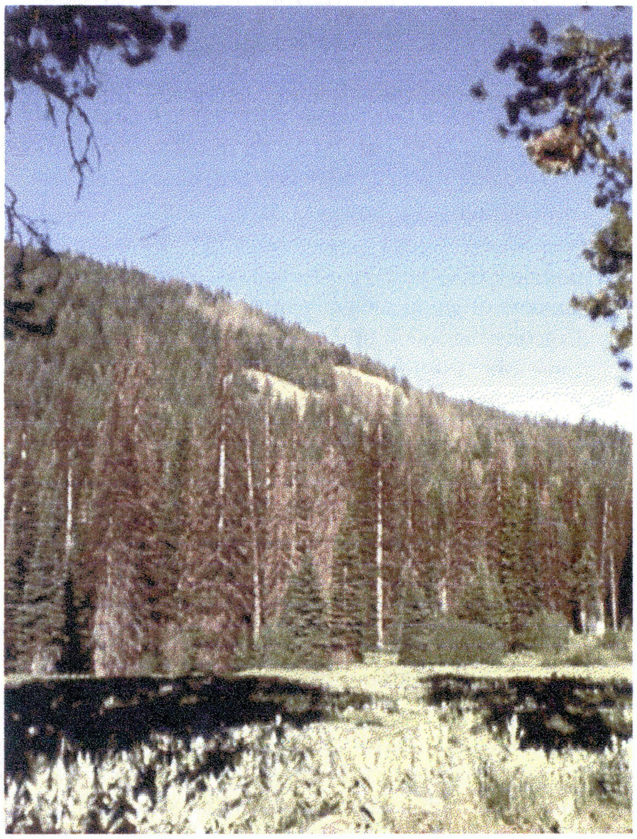


Figure 7. Engelmann spruce killed by spruce beetle on the Wallowa-Whitman NF.

Beetles prefer attacking the largest diameter trees first, especially in deep shaded stands. Unfortunately, usually the largest diameter trees are growing in the best sites; typically, riparian habitats. Populations, once in outbreak, commonly follow the drainages along river and stream courses, wherever the spruce occurs, leaving dead trees all along the length of these riparian habitats. Not only does this result in loss of stream shading, but these standing dead trees often become the source of heavy fuels for wildfires that can destroy all streamside vegetation. The 1989 Canal Fire on the

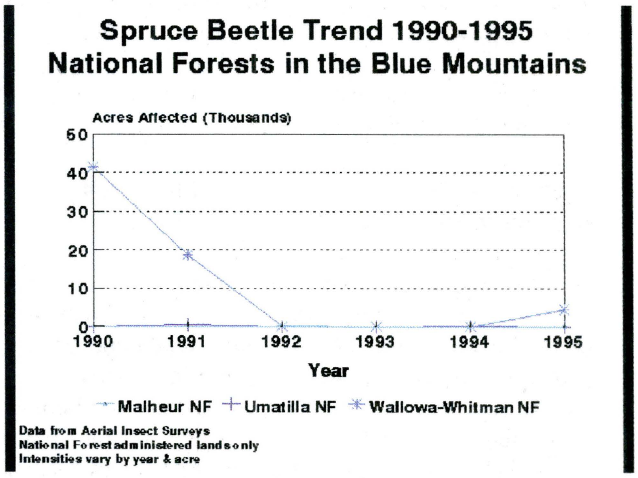
Wallowa-Whitman, as well as other recent fires (e.g., Twin Lakes Fire, 1994) either started in, or were fueled by, spruce beetle-killed Engelmann spruce (Fig. 8). This source of fuel for wildland fires becomes like a wick for fire to travel up and down these watercourses, ultimately resulting in significant stream and spawning habitat damage by siltation, elevated water temperatures, and other affects.

Trends and Population Levels

Spruce beetle populations declined throughout the Blue Mountains over the period 1990 through 1993 (Fig. 9). Populations occurred only on the Wallowa-Whitman NF in significant numbers during this recent outbreak. Minor acreage of spruce beetle-infested Engelmann spruce occurred on the Umatilla NF because of 1991 and 1992 windstorms that blew down large spruce and other conifers near Tollgate Guard Station, on the Walla Walla RD.

Though the spruce beetle-infested acres declined from 1990 through 1994, populations are still active is some stands that have been slow to be infested by beetles during this outbreak (Fig. 9). Populations of spruce beetle declined dramatically on the Wallowa-Whitman NF during 1991 and 1992. Having killed most spruce trees in drainages on the Pine and Wallowa Valley Ranger Districts, and Hells Canyon National Recreation Area, too few large spruce remained to continue to support high beetle populations after 1991 on those districts. It is difficult to find any live, large-diameter spruce anywhere on the north end of the Wallowa-Whitman NF today, except in the Eagle Caps. The last two years of insect detection flight could account for only 134 acres of trees killed by spruce beetle in 1992 and 102 acres killed in 1993 on the Forest. Spruce beetle-infested acres in the Blue Mountains increased slightly to 277 acres in 1994, and 4,793 acres in 1995 (Fig. 9).

Spruce beetle population on the other two National Forests (Malheur and Umatilla) have remained relatively low for the last several years. The Umatilla had 483 acres infested during 1991, probably in association with the blowdown from windstorms. Prompt action to remove the large-diameter, susceptible host trees helped to prevent serious build-up of spruce beetles in stands experiencing blowdown on the Walla Walla Ranger District. The only other areas mapped on either the Malheur or Umatilla National Forests with spruce beetle-killed trees included 8 acres on the Malheur in 1991, and 87 acres in 1995, and 10 acres on the Umatilla in 1993, 198 acres in 1994, and 74 acres in 1995. Most populations are expected to remain low in 1996. However, recent infestations of spruce beetle in fire-injured spruce associated with 1994 fires on the Long Creek Ranger District bear watching. The District is undertaking an aggressive approach of utilizing pheromone-baited trap trees and funnel traps, infested tree removal where possible, to mitigate this infestation before it develops to full-scale outbreak.


Spruce Beetle Trend 1990-1995
National Forests in the Blue Mountains

Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 9. Spruce beetle trend on National Forests in the Blue Mountains from 1990 to 1995.

The likelihood of another major spruce beetle outbreak occurring on the Wallowa-Whitman National Forest will be low for a number of decades to come due to the lack of suitable host trees. However, suitable hosts still exist at many locations on the Umatilla and Malheur National Forests. In most cases, host stands remain overstocked and at varying levels of risk to spruce beetles. Few cultural activities have occurred in these stands since the Forest Health Report was issued in 1991 (see Gast et al. 1991) that would materially change habitat conditions for spruce beetle and result in lower stand susceptibility to the beetle. Aside from a preventative strategy of maintaining healthy stand conditions and properly stocked and spaced stands, prompt action to remove large diameter windthrown trees and other significant sources of spruce beetle habitat that result from landscape-scale natural forest disturbances, and man-made events (e.g., logging and road-building), is essential to avoid major spruce beetle outbreaks in stands in the Blue Mountains. The high probability of spruce beetles developing into outbreaks under these disturbance regimes and causing not only the possible depletion of the spruce resource from stands, but also other significant indirect damage to non-timber resources dictates the need to take appropriate and prompt action to mitigate, or avoid altogether, spruce beetle buildups in these situations.

Douglas-fir Beetle (*Dendroctonus pseudotsugae* Hopkins)

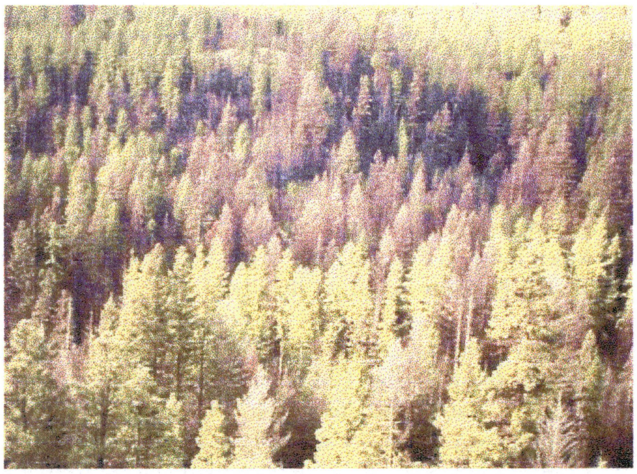


Figure 10. Douglas-fir beetle infestation in stand of Douglas-fir.

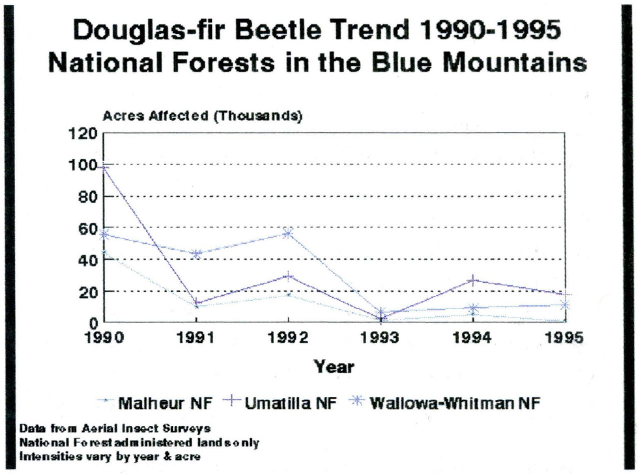
The Douglas-fir beetle (*Dendroctonus pseudotsugae*) (Fig. 10) is the most important bark beetle to Douglas-fir stands across the range of the host in western North America (Furniss and Caroline 1977). In the Blue Mountains, Douglas-fir beetle is normally considered a secondary insect that invades low vigor and recently dead trees (Gast et al. 1991). Habitat for beetles in which endemic populations are maintained include: windthrown trees, trees struck by lightning, or infected with root disease, dwarf mistletoe, or stem decay; and trees stressed by other factors such as drought, defoliation, wildfires, and snow breakage. In addition, high stumps and large diameter logging culls are also attacked by Douglas-fir beetles.

Outbreaks of Douglas-fir beetles typically result from major stand disturbances in which a large supply of suitable breeding habitat suddenly becomes available. Outbreaks normally subside when the factors causing the disturbance subsides. Several years may separate the termination of the outbreak and the decline of the disturbance factor causing the outbreak due to the high populations of beetles that build up during the disturbance event. Natural host resistance is the primary factor causing the collapse of most Douglas-fir beetle outbreaks, although natural enemies, weather, food supply, and other factors are important in contributing to the decline of outbreaks, as well. Large wildfires and weakening of many thousands of acres containing host trees by western spruce budworm, Douglas-fir tussock moth, and moisture stress, are principle factors contributing to the outbreaks of recent years. Old-growth stands and large, old Douglas-firs growing in riparian habitats have been especially damaged by Douglas-fir beetles in the Blue Mountains. Host trees growing in these stands are typically over-aged, have low vigor, and are competing with other trees and vegetation in overstocked conditions. In essence, they are ripe for an outbreak and become the primary focus for development of outbreak populations of beetles when weakened further by defoliation and drought stress.

Trends and Population Levels

As we have already mentioned, recent increases of Douglas-fir beetle populations in the Blue Mountains have been influenced largely by heavy budworm defoliation and drought-stress. Large diameter, mature or overmature, trees are those that are at greatest risk of being attacked and killed by beetles. Furniss et al. (1981) found that the average age of trees attacked by beetles exceeded 120 years. Walters (1956) said that Douglas-fir over 150 years old, especially those that are slow growing, are more susceptible than younger, more vigorous trees. In many of these older stands in the Blue Mountains, populations of Douglas-fir beetles increased to outbreak levels near the end of the budworm epidemic and caused substantial tree mortality. Over the past 6 to 8 years, we have observed bark beetle-caused mortality of stands with mature and overmature Douglas-fir on nearly every Ranger District that experienced moderate to high rates of budworm defoliation. In other cases, drought and overstocking, or drought in combination with Douglas-fir mistletoe, had predisposed mature or overmature trees to bark beetles. In contrast to most other areas where Douglas-fir beetles had become epidemic, these were typically stands where budworms had not been present, or did not severely defoliate crowns to significantly weaken trees. The Burns Ranger District, for example, experienced Douglas-fir mortality over the past several years by Douglas-fir beetles under these kind of conditions. In addition, Douglas-fir tussock moth defoliation contributed to increases in Douglas-fir beetles in some stands on the District during the last 3 or 4 years.

Douglas-fir beetle populations appear to have peaked in 1989--three years following the peak of the budworm outbreak in the Blue Mountains (see Gast et al. 1991). Populations on the three Forests have been declining since 1990 (Fig. 11). Populations in 1993 marked the lowest levels on nearly all three National Forests since beetle populations began to increase in 1987. Areas where bark beetles have increased, and have been killing small groups of trees each year in stands with heaviest budworm defoliation, will continue to have Douglas-fir beetle-caused mortality until the beetles have killed all or most of the larger diameter trees larger than 9 or 10 inches dbh, based on our observations. Recent studies by scientists from Oregon State University and the Pacific Northwest Research Station (U. S. Forest Service) have found the use of pheromones of the Douglas-fir beetle (both attractant and antiaggregation pheromones) to hold considerable promise for managing Douglas-fir beetle populations in the Blue Mountains (see for example, Ross and Daterman 1995). Treatments of stands on an experimental basis, and in a pilot control study, have been conducted on portions of the Wallowa Valley RD and the La Grande RD, respectively, since 1993. Results of these studies show that pheromone-baiting of trap-trees and aggressive removal of infested trees, and use of antiaggregative pheromones can effectively manipulate populations to either prevent high-risk stands from becoming infested or help to lower beetle populations to reduce the number of new trees from being attacked.



Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 11. Douglas-fir beetle trend on National Forests in the Blue Mountains from 1990 to 1995.

Though levels of Douglas-fir beetles have declined considerably since building up populations in response to defoliation and drought-stressed trees, levels of some populations now seem to be maintained at these lower levels in trees with large mistletoe brooms. We are somewhat concerned about the risk these trees pose to wildfire, as the large, dead, "broomed" crowns of these trees are highly flammable as fuel ladders and could help carry surface fires into the crowns of the surrounding stands upon ignition. Although these large mistletoed trees enhance ecosystem function by providing roosts, perches, and nesting sites for a number of bird species, and habitat for flying squirrels and other small animals (see mistletoe section below), they may be less important from a wildlife standpoint after they are dead and no longer contain live foliage. Because of the hazard of these dead trees to fire, the value of leaving them in place in certain stands may need to be re-evaluated.

In contrast to the apparent general decline of Douglas-fir beetle populations throughout much of the Blue Mountains by 1993 (Fig. 11), populations on portions of the La Grande Ranger District and adjacent areas on the North Fork of John Day Ranger District increased slightly during the last couple of years. Field observations of areas on the La Grande Ranger District showed significant levels of Douglas-fir beetle activity along portions of Highway 244, on the slopes within the Grande Ronde River drainage, and scattered throughout stands along the Forest Service 21 Road, and other areas of the District north and east of the 21 Road over the last several years. Also, the areas on the North Fork of John Day Ranger District along the Forest Service 54 Road, in the vicinity of Lane Creek, had similar levels of Douglas-fir beetle activity apparent the past couple of years.

Much of these areas contain stands that had been severely defoliated by budworm and in which bark beetles had become epidemic, causing considerable mortality to Douglas-firs and grand firs. Douglas-fir beetle populations have continued to kill groups of large-diameter trees associated with the severe budworm defoliation and drought stress each year for the past 4 or 5 years. Now, these beetle populations, having increased to high numbers, are not only killing trees in the heavily defoliated areas, but seem to be maintaining populations in certain stands, and perhaps increasing numbers in others that were less severely defoliated. Probably, much of this tree mortality was not mapped during aerial insect detection surveys during 1993 because many of these trees had not faded by the time the aerial surveys were flown that summer. Many tree crowns began to turn yellow and red in 1994 as those trees attempted to draw moisture from soils that were no longer frozen, but they are unable to do so because water conduction through the bole to the crown had been blocked by a blue-stain fungus, *Ophiostoma pseudotsugae*, introduced by the bark beetles when the trees were attacked the previous year.

In general, Douglas-fir beetle populations appear to be on the wane, given the trends of the past few years. It is doubtful that populations will continue to build in many overstocked stands, as too few of the old large-diameter trees remain to carry the population. Also, with the collapse of budworm and recovery of defoliator and drought weakened trees, hosts are becoming more vigorous and will be able to soon resist attacks by beetles. In addition, poor brood production and survival will result as smaller diameter, more resistant trees are attacked by Douglas-fir beetles. The natural resistance of trees will ultimately lead to the collapse of the Douglas-fir beetle epidemic. However, it may take several more years for the collapse of beetle populations to occur.

The increases in Douglas-fir beetle activity on portions of the La Grande and North Fork of John Day Ranger Districts are probably not unique. Undoubtedly, there are many other locations with stands of similar conditions to these in the Blue Mountains that also show increased activity of Douglas-fir beetles. The magnitude of this bark beetle activity was probably unprecedented in pre-settlement times. While outbreaks of Douglas-fir beetles were episodic in stands in centuries past, the magnitude and severity of tree mortality in recent years probably greatly exceeds anything these stands experienced in the past. The association with increased acreage of Douglas-firs along with true firs resulting from fire exclusion and other practices since the turn of this century, and the predisposition of Douglas-firs to attack by bark beetles that resulted from budworm defoliation and drought-weakened trees, have created conditions favorable to buildup of beetle populations over broad areas in the Blue Mountains. The ability of these stands to sustain high levels of Douglas-fir beetle activity for an extended period in modern times, given past management practices, should not be unexpected.

As with other insect problems that have occurred in the Blue Mountains over the last couple of decades, changes in vegetation conditions that cause these stands to be susceptible to Douglas-fir beetle (e.g., overstocking, stand compositions, etc.) have been slow to occur. Stands today, are very much the same as those of 4 or 5 years ago. Although risk of stands to Douglas-fir beetle may be slightly lowered as the largest, oldest, and most susceptible Douglas-firs are killed by beetles in these stands, residual host trees will continue to grow older and larger, and become more competitive in stands with time so that these stands will eventually become highly susceptible once again in some future decade. Management of stands to maintain appropriate levels of stocking, species composition, and structure is necessary to mitigate tree losses from beetles to within acceptable levels for the resource emphasis and management direction for the area.

Fir Engraver (*Scolytus ventralis* LeConte)

Fir engraver (*Scolytus ventralis*) (Fig. 12) is the most important bark beetle of true firs in the Blue Mountains (Gast et al. 1991). Grand fir and white fir are the main hosts for fir engravers in the Blue Mountains. Subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) is an occasional host, and under rare situations fir engravers will attack Engelmann spruce and Douglas-fir.

Fir engraver is normally considered a secondary insect that is attracted to trees that are unhealthy, having reduced vigor due to age, competition, disease, and other factors (Berryman and Ferrell 1988). Outbreaks of fir engraver may occur when trees are continually, and severely weakened by defoliation or drought. In most cases, these outbreaks are spotty with relatively small pockets of mortality scattered over wide portions of the landscape. Certain stands, especially those growing in thin, rocky mineral soils can experience nearly complete mortality of the fir over areas several acres in size. These levels of tree mortality from fir engraver outbreaks are more common in other parts of the insect's range, such as in California, then they are in the Blue Mountains. Nevertheless, they do occur on occasion in the Blue Mountains.

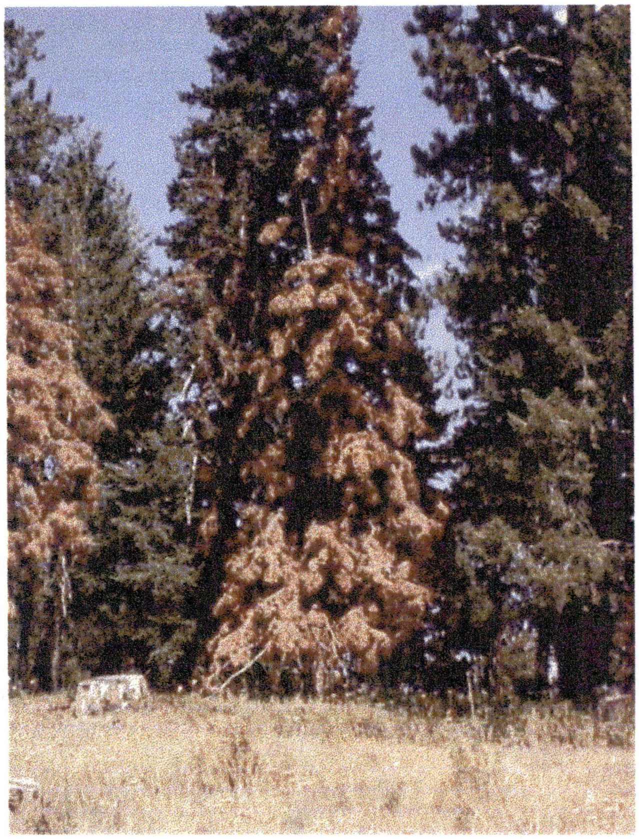


Figure 12. Grand firs killed by fir engraver beetle.

Endemic levels of fir engraver-caused top-kill, branch, or whole-tree mortality are fairly common in the Blue Mountains. The fir engraver is capable of establishing egg galleries in host tree boles, tops, or larger branches without causing the death of it host. Superficial wounds to sapwood in non-lethal fir engraver attacks eventually heal over by cambial growth and differentiation into phloem tissues. These galleries eventually become incorporated within the tree as bark grows over the wounds, often taking on a roughened appearance at the exterior surface of the bark. The ability of fir engraver to maintain relatively high, but mostly non-lethal endemic populations in stands, enables the beetle to increase populations to outbreak quickly in the presence of major stand disturbances. Under normal moisture conditions, in the absence of defoliators, this insect is highly correlated with incidence of root disease in host trees. Though populations can increase rapidly and cause tree mortality over sometimes thousands of acres, outbreaks are usually short-lived, and decline just as rapidly.

Trends and Population Levels

Much like the Douglas-fir beetle trends, fir engraver trends corresponded with budworm defoliation and drought. Beetle populations peaked in 1989, having increased in trees weakened after several years of drought on top of nearly a decade of budworm-caused defoliation (see Fig. 2). The response of populations of fir engravers, which increased near the end of the budworm outbreak, were similar to bark beetle population increases that occurred during the end of the tussock moth outbreak in northeast Oregon and southeast Washington during the 1970's (Wright et al. 1984). Both defoliation and drought are important factors that predispose true firs to attack by bark beetles (Gast et al. 1991).

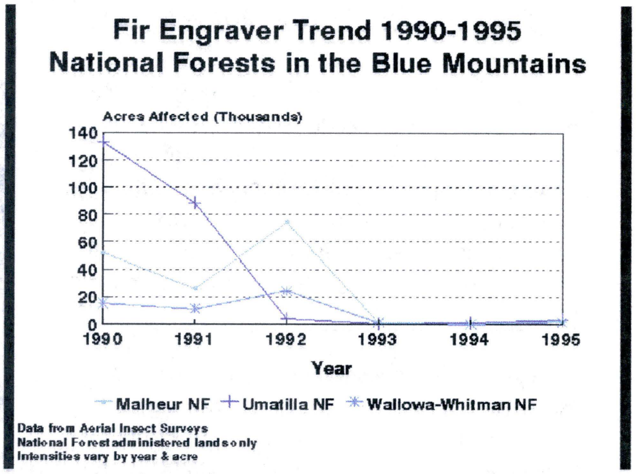


Figure 13. Fir engraver beetle trends on National Forests in the Blue Mountains from 1990 to 1995.

The major fir engraver population fluctuations and trends (Fig. 13) followed population fluctuations of the spruce budworm in the Blue Mountains (compare Figs. 3 and 13), but beetle increases were delayed by a year or two. The resurgence of budworm populations in 1990 and 1991 was followed to some extent by fir engraver increases on the Malheur NF and Wallowa-Whitman NF in 1992, whereas fir engraver populations continued to decline on the Umatilla (Fig. 13). This again, illustrates the time-lag of bark beetle population response to changes in susceptibility of trees resulting from budworm defoliation and drought. All three National Forests have shown decline in acreage of fir engraver-caused tree mortality since 1993,

With populations of budworm in collapse, and trees beginning to recover, populations of fir engraver should continue to remain low. Lower populations of beetles should result in normally low levels of tree mortality again. Drought, on the other hand, is still a significant factor affecting fir engraver populations. A continuation or return of drought would likely cause beetle populations to continue to successfully kill weakened trees (although at considerably reduced levels) by maintaining good brood survival and elevated population levels in poor vigor trees for a few more years. As factors influencing the susceptibility of trees and success of broods change with improved moisture conditions, reduced competition stress on trees, increased vigor of trees, and unfavorable weather conditions for brood production, growth, and survival, populations should return to endemic levels. At these levels fewer trees are killed each year than now, and the killing of individual branches or occasional tops of true firs, are more typically seen with these endemic populations.

Since tree resistance to attack is related to the amount of current and stored photosynthate that is available for defense (Christiansen et al. 1987; Wright et al. 1979), even the relief of budworm defoliation pressure and drought-stress may not totally eliminate fir engraver beetle attacks in severely overstocked stands, because the carbon stores of trees are affected by tree competition (e.g., Waring et al. 1987). The role of carbon, specifically as carbohydrates, and the actual flux of these compounds for the synthesis of protective chemicals is greatly influenced by the interaction of trees with climate and various components of their environment, including defoliation, drought, and overcrowding that leads to reduced assimilation through shading of foliage (e.g., Christiansen et al. 1987), among others. In view of this, Christiansen et al. (1987) hypothesized that:

> *". . . the ability of trees to withstand attacks by bark beetles and their associated fungi is linked to the amount of carbohydrates that can be utilized directly for defensive wound reactions. Therefore, any environmental factor that restricts the size of the canopy or its photosynthetic efficiency can weaken a tree's resistance."*

Though most of the tree killing by fir engraver is now over, overstocked stands, and those where root disease is prevalent, will continue to be susceptible and experience mortality and episodic--although small scale--outbreaks in future years. Overcrowding and root diseases, although addressed in forest health prescriptions, have not been altered through silvicultural activities except for on a very small proportion of the areas needing treatment since issuance of the Forest Health Report (see Gast et al. 1991). Hence, many hundreds of thousands of acres of true fir-dominated mixed conifer stands in the Blue Mountains are still highly susceptible to fir engravers today.

Like Douglas-fir beetle populations, the activity of fir engraver beetles will again increase to higher levels the next time another outbreak of tussock moth or spruce budworm defoliates and weakens broad expanses of suitable, multi-layered stands of timber. Defoliator outbreaks readily create the habitat conditions necessary for bark beetle populations to rapidly build to epidemics. Managing vegetation in stands to increase the proportion of resistant seral species and use of regeneration harvesting methods will be crucial to managing both defoliator and bark beetle populations under the ecosystem management approach of the future.

Mountain Pine Beetle (*Dendroctonus ponderosae* Hopkins)

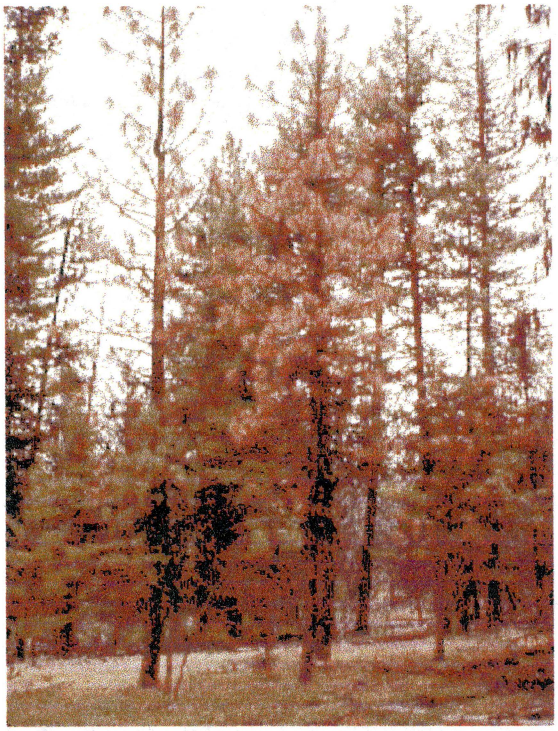


Figure 14. Ponderosa pine killed by mountain pine beetle.

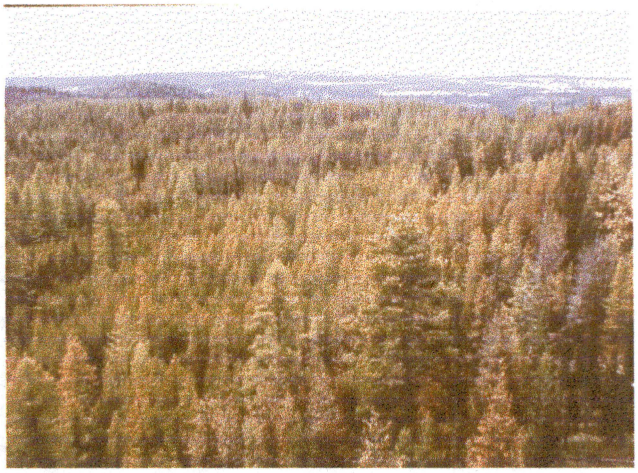


Figure 15. Lodgepole pine beginning to fade after infestation by mountain pine beetle.

The mountain pine beetle is considered to be the most destructive of all bark beetles occurring in the West (Furniss and Caroline 1977). Loss of host trees can lead to significant declines in timber volumes over large areas of the forest, and result in enormous portions of forested areas being left in non-stocked or understocked condition. In addition, adverse effects on wildlife populations, hydrologic conditions of watersheds, recreation values, and other resources have been documented (Gast et al. 1991).

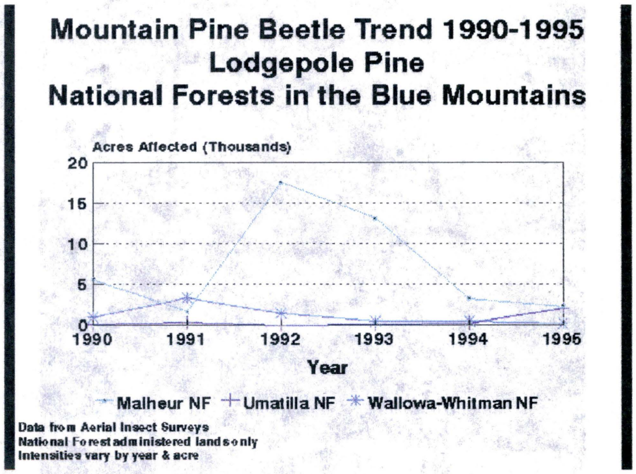
The mountain pine beetle attacks and kills a number of host species in the genus *Pinus*, but within the Blue Mountains, ponderosa pine (*P. ponderosae* Laws) (Fig. 14), and lodgepole pine (*Pinus contorta* Dougl.) (Fig. 15) are the most important. Western white pine (*P. monticola* Dougl.) and white bark pine (*P. albicaulis* Engelm.) are also important hosts in the Blue Mountains, but these species are not widely distributed. As more acreage is planted with western white pine, this tree will eventually become more important as a host for mountain pine beetle in the future.

Outbreaks of mountain pine beetle figure prominently in the history of the Blue Mountains; major epidemics have been recorded since the turn of this Century (see Burke 1990; Gast et al. 1991). Outbreaks that occur in high-risk stands oftentimes move into stands of lower risk due to the production of large numbers of aggressive beetles, and due to "spillover," where the pheromone system of beetles directs attracted beetles away from trees already under mass attack, to unattacked trees nearby. Stands that have high risk of attack by beetles are those that are pure pine or nearly pure, are essentially even-aged, have average tree diameters exceeding 7 inches d.b.h., and have stem basal areas exceeding 150 sq. ft per acre in the case of ponderosa pine and 100 sq. ft. per acre for lodgepole pine. Generally, these are stands where average age of lodgepole pine exceeds 80 years, and ponderosa pine is between 50-100 years old (Gast et al. 1991). Outbreaks collapse from a number of factors; chief among which include depletion of suitable hosts, natural host resistance, weather, and others. Some outbreaks may last 20 or more years.

Trends and Population levels

In the Blue Mountains, both lodgepole pine and ponderosa pine serve as hosts for the mountain pine beetle. During the last major outbreak of this bark beetle from roughly 1967 to 1986 (see Gast et al. 1991), much of the mature and overmature lodgepole pine was killed, and significant--though lesser--acreages of second-growth ponderosa pine were killed, as well. Today, little lodgepole pine of the susceptible age and size remains to support a mountain pine beetle outbreak in that host. Most stands today are younger, smaller in diameter, and typically greatly overstocked. These stands, however, are not susceptible to mountain pine beetles because the uniformly small diameters and thin bark on these trees are unable to support brood development and survival.

Levels of mountain pine beetle activity in lodgepole pine have been quite low on both the Umatilla and Wallowa-Whitman National Forests over the last six years (Fig. 16). Populations on the Malheur--mostly on the Prairie City RD--increased significantly in 1992; but have been declining since then. The levels of mountain pine beetle activity in lodgepole pine is expected to remain low over most areas for probably a couple of decades or more due to the lack of suitable-sized lodgepole pine host trees capable of producing outbreak populations and sustaining high levels of lodgepole pine mortality. Smaller localized epidemics of mountain pine beetle may occur in older stands that have received little in the way of vegetation management in the past. Ranger Districts in the Blue Mountains have conducted thinning activities in a number of stands, but many more acres remain overstocked and have yet to be brought under stand density management, based on our observations. Some commercial stands and plantations, and areas such as campgrounds or other administrative areas include dense stocking of second-growth ponderosa pines as well as lodgepole pine on these sites. Some of these areas are at risk now, or will become at risk within a decade or two as trees on these sites grow older and canopies close. Some examples of areas that are recently experiencing considerable mountain pine beetle activity include several campgrounds on the Baker, Unity, Prairie City, Long Creek, Burns, and North Fork of the John Day Ranger Districts.



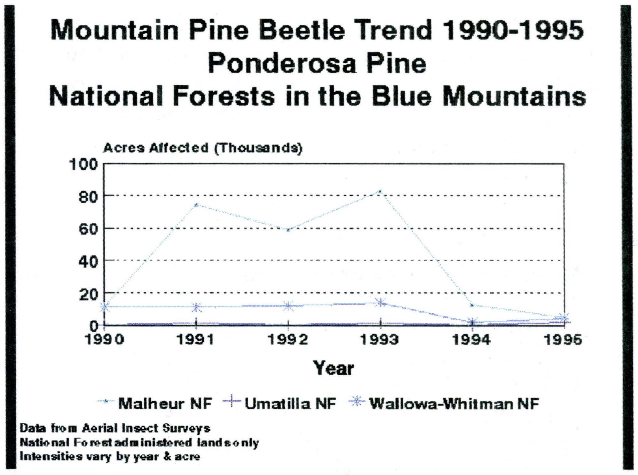
Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 16. Mountain pine beetle in lodgepole pine trends on National Forests in the Blue Mountains from 1990 to 1995.

Many young stands of even-aged ponderosa pine were thinned in the Blue Mountains during the 1970's. After 20 or more years of growth, trees in those stands have greatly expanded their root systems and crown biomass, and have increased in diameter to where they are competing for soil moisture, root space, and light. Many of these stands have achieved a size and stocking level that place them at considerable risk of attack by mountain pine beetles. We often say these stands are "set-up" for a bark beetle outbreak because the conditions of the stand provide the right habitat and environment in which mountain pine beetles can successfully attack trees and produce brood, and rapidly increase numbers to outbreak levels (usually in a matter of 2 or 3 years). Usually, all that is needed to trigger an outbreak is an event or condition that causes a large number of trees to become attractive to the beetles so that attacks are initiated. Several attacked trees may initially serve as foci to draw in and concentrate many beetles in the susceptible stand. Soon, beetles begin to "spill over" into adjacent trees when "focus trees" become saturated by attacking beetles. This often results in the killing of healthy trees.

We believe drought-stress is the underlying factor that has been responsible for weakening trees of nearly all species in the Blue Mountains. Drought stress weakens trees and enables mountain pine beetles to increase to levels capable of killing larger groups of trees in overstocked stands of pure, or nearly pure second-growth ponderosa pine. While ponderosa pines show considerable drought resistance because of their deep-reaching taproot and long and strong lateral roots (Betts 1953), they are ultimately subject to the effects of prolonged, severe drought like any other tree species; in time, they too become weakened and reach a condition where they are highly susceptible to bark beetles.

An increase in activity of mountain pine beetle in ponderosa pines related to overstocked stands and moisture stressed trees resulted in the trends shown in Figure 17. All three National Forests in the Blue Mountains showed some increases in beetle activity in ponderosa pine from 1990 to 1993, but none quite as dramatic as the Malheur NF. Nearly 83,000 acres of ponderosa pine have been mapped with some level of mountain pine beetle infestation on the Malheur National Forest during the 1993 aerial insect detection survey. This was the peak year of the most recent mountain pine beetle infestation, based upon infested acres mapped over the past six years. Most of the acres infested with mountain pine beetles in 1993 were concentrated on the Burns Ranger District, although quite a bit of acreage on the North half of the Malheur NF was mapped with various levels of mountain pine beetles, as well. By comparison, the Umatilla and Wallowa-Whitman National Forests had considerably fewer acres of mountain pine beetles in ponderosa pine mapped in 1993, with 1,769 and 14,285 acres infested, respectively. Roughly half of the acres mapped on the Umatilla NF were on the North Fork of John Day RD. On the Wallowa-Whitman NF, most of the mountain pine beetle activity centered on the Baker and Unity Ranger Districts near Dooley Mountain and Black Mountain.



Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 17. Mountain pine beetle in ponderosa pine trends on National Forests in the Blue Mountains from 1990 to 1995.

Clearly, most of the mountain pine beetle increases are occurring on the drier pine sites of the central and southern portions of the Blues. However, it is equally clear that the influence of drought on any overstocked stand of ponderosa pine has increased the susceptibility of these stands to bark beetles. That these beetles can increase at an alarming rate under ideal conditions, and result in considerable mortality to the pine resources (cf. Pitman et al. 1982; Sartwell 1971), suggests that stand management practices of thinning overstocked stands before beetles have an opportunity to increase would be prudent, under the circumstances.

We believe the current conditions of overstocking and locally high populations of mountain pine beetles will continue to bring about fluctuations of beetle populations from endemic to outbreak levels for several years to come. Populations of beetles have been slowly building in overstocked stands for a number of years, but over the last 5 or 6 years we have witnessed a much more rapid buildup of beetles in some locations than in the past.

Typically, mountain pine beetle outbreaks in ponderosa pine develop slowly (Sartwell and Stevens 1975). After an outbreak begins, the subsequent number of infested trees increases to a level of about 30 to 150 trees per acre per year, reaching this level by the third to fifth year, then declining after that (Sartwell 1971). An outbreak will often run its course from onset to collapse within ten years, but individual outbreaks can last up to two decades (Pitman et al. 1982). Over this period, the bark beetles can kill as much as 60 percent of the trees and 80 percent of the stand volume (Pitman et al. 1982). The loss of future fiber volume, negative effects on non-timber resource values, and the increased risk of stand-replacing wildfires are typically associated with this level of bark beetle activity. Thinning prescriptions in second-growth ponderosa pine stands reduce competition, increase vigor, improve tree growth, and provide various degrees of resistance to mountain pine beetles. Appropriate thinning levels have been recommended by Pitman et al. (1982).

As with the mixed conifer stands, the ponderosa pine plant communities have changed little, overall, since the Forest Health Report was issued in 1991 (see Gast et al. 1991). This has occurred in spite of some efforts to annually thin overstocked acres on Districts in the Blue Mountains. On the other hand, there are so many acres currently overstocked that it is impossible to bring them all under stocking level control except under the strategy of maintaining a continuous and aggressive thinning program over the course of several years. Preventative measures such as thinning these overstocked stands result in reduced risk to bark beetles, promote healthier stands for the benefit of all resources, and bring stands closer in line with the historic range of variability for these pine communities, given the role of fire in the past. In addition, thinning can help to achieve old-growth objectives sooner in those stands that have that as their management objective (Cochran et al. 1994).

Western Pine Beetle (*Dendroctonus brevicomis* LeConte)

Western pine beetle is an important mortality agent of ponderosa pine throughout the range of pine in western North America. Ponderosa pine is the only host for this beetle in the Blue Mountains of northeastern Oregon and southeastern Washington.

Western pine beetles are often associated with mountain pine beetles in killing of pole- and small sawlog-size ponderosa pines (Fig. 18); but, they are also well known as the primary insect-related mortality factor in overmature, slow-growing veteran ponderosa pines. During the times when old-growth ponderosa pines were still abundant, one well-known entomologist (in his treatise on the insect enemies of California pines and their control) termed the western pine beetle, ". . . *California's most destructive forest insect*" (see Keen 1928). Most early entomologists in the West considered western pine beetle to be "forest enemy number one" (Gast et al. 1991). This epithet is no longer accurate today, largely due to the harvest of most of the abundant old pines of the past, from today's forest ecosystem. Nevertheless, western pine beetle still remains as the most common insect-enemy of overmature, slow-growing, decadent, or diseased and root-rotted pines (Gast et al. 1991).

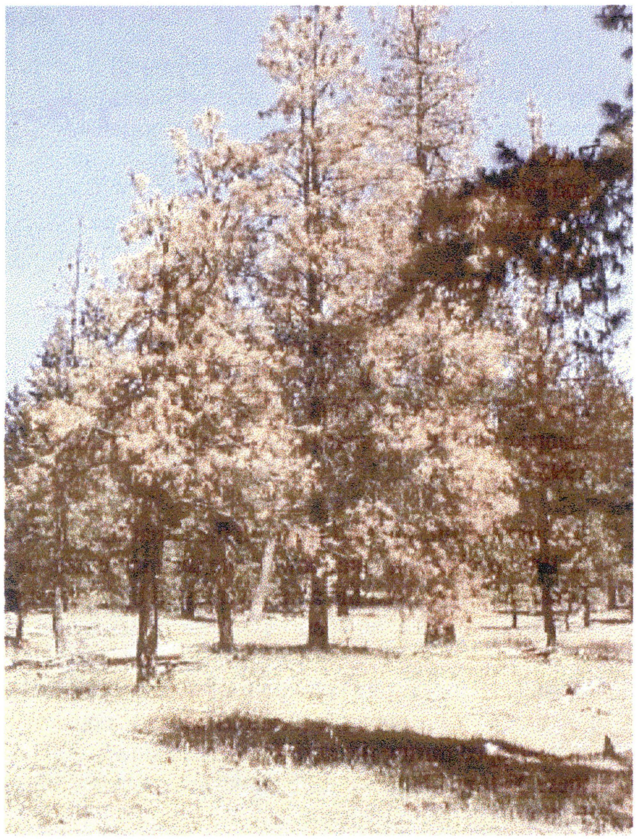


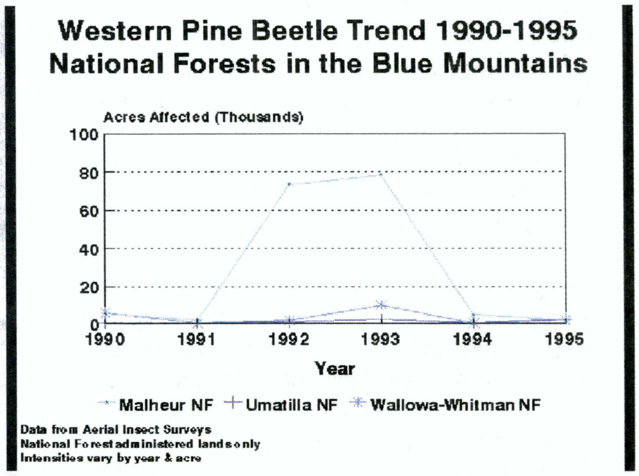
Figure 18. Ponderosa pine killed by western pine beetle.

In addition to the high susceptibility of decadent overmature trees, pines of most age-classes that are weakened by stand stagnation, lightning, fire, and other factors are also favored habitat for these beetles. Population buildup is often promoted by a prolonged period of drought stress, and many outbreaks in the past that resulted from trees weakened by drought have been documented (Gast et al. 1991).

The usual habit of western pine beetle is to breed in a few overmature trees, or in others that have been weakened by other agents, but under favorable conditions and an abundance of fresh host material, beetles can increase numbers quickly to become outbreaks. Beetles become considerably more aggressive under epidemic conditions and kill apparently vigorous trees of nearly all size classes providing the bark is thick enough to protect beetles and provide for their nutritional requirements.

Trends and Population Levels

Prolonged drought resulting in tree moisture stress, along with overstocking of pine stands, has led to increased susceptibility of the ponderosa pines in the Blue Mountains to western pine beetles in much the same way that pines have become susceptible to mountain pine beetles over the past decade or so. Indeed, the increasing trend of acres infested by western pine beetles from 1991 through 1993 (Fig. 19) follows much the same patterns of infested acres mapped for mountain pine beetles in ponderosa pine during the same period (compare Figs. 17 and 19). Western pine beetle populations, especially on the Malheur NF, increased significantly between 1991 and 1992; whereas, bark beetle population increases on the Umatilla and Wallowa-Whitman were considerably less dramatic (Fig. 19).


Western Pine Beetle Trend 1990-1995
National Forests in the Blue Mountains

Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 19. Western pine beetle trends on National Forests in the Blue Mountains from 1990 to 1995.

As with the mountain pine beetle in ponderosa pine, most of the western pine beetle activity on the Malheur NF also occurred on the Burns Ranger District during the 1991-1993 seasons. The Prairie City Ranger District also had a fair amount of acreage infested with western pine beetle in 1993. Rapidly increasing beetle populations on the Malheur NF resulted in beetle-killed pine areas increasing from 1,832 acres mapped in 1991, to 73,598 acres mapped in 1992, to 78,764 acres mapped in 1993. A sharp decline in beetle-infested acres occurred in 1994, and this low trend continued into 1995 (Fig. 19).

By comparison, infested acres on the Umatilla and Wallowa-Whitman National Forests increased during the 1991 to 1993 period at a much lower rate than increases on the Malheur NF for this period. Aerial surveys of the Umatilla NF showed the acreage infested by western pine beetles increased from 322 to 905 acres in the 1991 and 1992 survey years, respectively, and increased again to 2,295 acres in 1993--about half of which was on the Heppner RD. During this period, western pine beetle populations on the Wallowa-Whitman National Forest increased from 264 acres in 1991 to 2,012 acres in 1992, and to 10,309 acres in 1993. The Baker and Unity Ranger Districts were the locations on the Wallowa-Whitman NF where most of the western pine beetle activity was mapped during the aerial insect detection survey. Although populations of western pine beetles declined on these National Forests in 1994, a slight increase was recorded for both the Umatilla and Wallowa-Whitman National Forests in 1995. This, we suspect, was due to the increases of the three major bark beetle species in ponderosa pine following windstorms in 1994 that uprooted whole trees and weakened others by breaking tops off of larger trees. These events encouraged the further buildup of pine engraver beetle populations (*Ips pini*) already at high levels due to improper treatment of pine slash on nearly all land ownerships, as well as increases of populations of mountain pine beetle and western pine beetle.

The increase in western pine beetle populations during the past several years illustrates the relative susceptibility of pine stands to bark beetles that exists throughout the Blue Mountains region. This again points up the need to thin overstocked pine stands before beetle populations start building up, reach outbreak proportion, and cause unacceptable levels of tree mortality. Pine stands today are still as overstocked as than they were five years ago. Stands will continue to grow into higher risk categories in the absence of stocking level control, placing the pine resource, and other non-timber resource values at increased probability of damge--whether directly or indirectly--from western pine beetles.

Pine Engraver (*Ips pini* (Say))

The pine engraver beetle (*Ips pini*) (Fig. 20) is an important forest insect in North America and Mexico. Pine engravers are relatively small native bark beetles that breed in *Pinus* spp. and occasionally spruce (*Picea* spp). It is one of the most common forest insects, occurring transcontinentally in almost all pine species, and at times becomes a serious forest pest (Furniss and Carolin 1977).

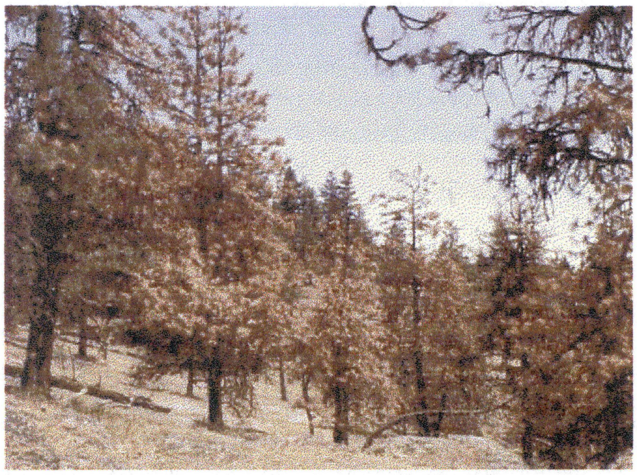


Figure 20. Ponderosa pines killed by pine engraver beetles.

The pine engraver is typically found in association with populations of mountain pine beetle and western pine beetle in ponderosa pines, and in association with mountain pine beetle in lodgepole pine. This insect commonly attacks the tops of trees and sometimes larger branches, whereas mountain pine beetles and western pine beetles attack other locations of the bole, although egg galleries of all these beetles often overlap in their areas of infestation. Small populations of pine engravers may build up in localized areas and sometimes kill thickets of lodgepole or ponderosa pine saplings or poles within the vicinity of recently created accumulations of untreated thinning or logging slash (Livingston 1979).

Populations often build to outbreak during droughty years, particularly whenever the average precipitation for the period April to September is 90 percent or less than normal (Dolph 1971). Besides drought, Dolph identified three other conditions that foster pine engraver outbreaks: (1) High beetle populations; (2) an abundant amount of suitable or fresh slash; and (3) a stagnated stand of trees having poor vigor. Where these conditions exist in pine dominated communities in the Blue Mountains, we can expect to see varying levels of pine engraver activity.

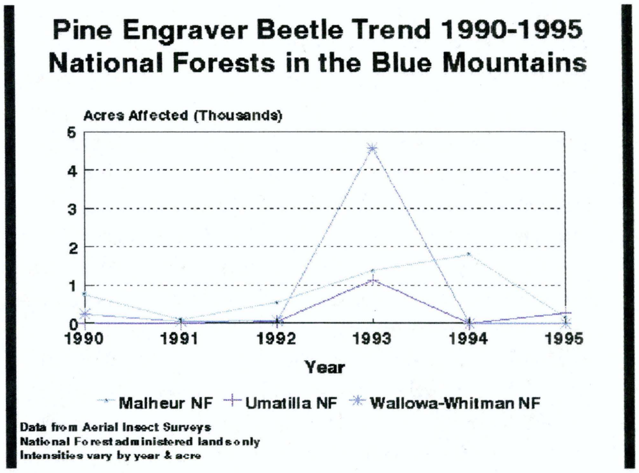
Outbreaks that develop can cause severe tree mortality in localized areas, especially on dry, rocky scarps and sites with low productivity and poor soils. Under prolonged or extreme drought conditions, these patches of tree mortality can be quite widespread over the landscape. Fortunately, these outbreaks, though severe, are usually short-lived, typically lasting no more than a season or two. However, infestations involving mountain pine beetle and western pine beetle can result in much more severe tree mortality; and, these insects--being much more aggressive--can prolong outbreaks for sometimes several years.

Trends and Population Levels

Like other bark beetle species in pine plant associations, pine engravers have been on the increase on the three

Forests in the Blue Mountains the past 5 or 6 years. Though pine engraver populations are typically low compared to western pine beetle and mountain pine beetle, our recent field observations reveal an upswing in areas infested that are not necessarily reflected in aerial insect detection survey data (Fig. 21). Part of the reason for this is that it is sometimes difficult to separate pine engraver infestations from those of mountain pine beetle and western pine beetle due to similarities in the appearance of faded foliage of trees killed by these insects when viewed from an aircraft. It is, of course, especially difficult to classify cause of tree mortality from the air when these three insects all occur together in the same tree, as they oftentimes do. Most accurate information, then, comes from close inspection of trees from ground-based surveys and observations used to validate infestation maps produced during aerial detection flights.

The largest increase from a previous year was mapped for the Wallowa-Whitman NF in 1993. Increases were roughly fourfold greater than those of the Umatilla and Malheur National Forests during 1993. Most of the pine engraver beetle activity was on the Baker RD; much of it associated with the large areas of mountain pine beetle activity near Dooley Mountain and Black Mountain, and around Phillips Reservoir. A total of 4,591 acres were mapped as infested with varying levels of pine engraver beetles over the whole Wallowa-Whitman National Forest in 1993. Acres mapped as infested with pine engraver beetles on the Umatilla and Malheur National Forests in 1993 were 1,139 acres and 1,388 acres, respectively. In 1994, pine engraver populations continued to increase on the Malheur NF, but declined on the other Forests. Populations of these beetles were at approximately equal levels on all three National Forests in the Blue Mountains in 1995 based on aerial detection survey data (Fig. 21). However, our observations, as indicated above, lead us to believe that pine engraver populations are much higher and more widespread across the Blue Mountains than suggested by the aerial survey.



Data from Aerial Insect Surveys
National Forest administered lands only
Intensities vary by year & acre

Figure 21. Pine engraver trend on National Forests in the Blue Mountains from 1990 to 1995.

Normally, year to year tree mortality from pine engravers is low. Most of this mortality is to sapling and pole-size thickets near units that have been recently thinned or logged. Moisture deficits that create plant moisture stress in the upper bole of larger trees may be critical in detecting trees that will be top-killed by pine engravers since this portion of the bole is the location where pine engraver attacks are first initiated (Dolph 1971).

It is difficult to predict what populations of pine engraver beetles are going to do in the next year or two. A lot depends on soil moisture conditions over this period. Clearly there is a relationship between percent of normal precipitation during spring and early summer months, and pine engraver population increase (Dolph 1971; Livingston 1979; McGregor et al. 1977), but other factors are involved as well, including those mentioned above plus soil type, stocking, age, site, and level and nature of stand disturbance (Dolph 1971). Abundant moisture in winter snow packs and heavy spring precipitation, especially from April through July, may preclude 1996 from being another "Ips" year (a year with unusually high pine engraver beetle-caused tree mortality). Since pine engraver beetle outbreaks usually last no more than a generation or two, the Blue Mountains pine stands may be facing at least one more year of higher than normal levels of pine engraver-related tree mortality. Management of slash created during thinning and harvesting activities can significantly reduce pine engraver-related tree mortality. Dolph (1971) and Livingston (1979) list several factors to consider during tree harvesting and thinning activities to reduce potential problems from pine engraver beetles. Aggressive implementation of these practices will assure tree mortality levels will approximate historic levels that were once regulated by the natural fire regimes in these drier Blue Mountains plant communities. Fluctuations of pine engraver populations will continue to occur across the landscape where pine components are well represented in stands. Careful practices by all landowners in managing slash created in the harvest or thinning of pine will assure that these fluctuations, and attendant tree mortality, remain at acceptable levels.

STATUS OF FOREST DISEASES

Most tree diseases in the Blue Mountains have increased in incidence and severity since the mid-1800's as species mixes and stand structures have changed, and predisposing factors have increased, rendering stands more susceptible to infection and impacts. Changes in disease incidence and severity have changed only a little in the last five years. While forest insect effects shift dramatically between endemic and epidemic population levels experienced during normal boom and bust cycles, activity of disease pathogens remains much more constant, shifting slowly with changes in stand susceptibility. Documented increases for insects draw upon the annual aerial survey flown by the Region. No such annually updated database exists for tree diseases so good data are lacking. This is partially because most tree diseases are not readily observable from the air. Causes of mortality may be misidentified; for example, tree killing by root diseases has usually been attributed to bark beetles (which are usually involved). Even permanent plot and stand exam information are not considered reliable. Most of the valid information on status and trends of forest diseases are from observations made by District and Forest silviculturists, Regional and Zone pest specialists, and research scientists, as well as some specific pest biological evaluations and administrative studies (e.g., Schmitt *et al.* 1991). As a recent source of reference, Lehmkuhl *et al.* (1994) investigated changes in historic to current insect and disease risks in several river basins in the Oregon and Washington, including the Grande Ronde. Risk ratings for three dwarf mistletoes, three root diseases, and stem decay have been used for watershed-level analysis on the Forest over the last two years (Scott and Schmitt *in review*). Recent trends of forest diseases from 1990 to 1996, including current management concerns, and emerging new issues, will be highlighted in this chapter.

DWARF MISTLETOES

There are four dwarf mistletoes in the Blue Mountains, each of which has a different primary host: Those that occur on Douglas-fir (*Arceuthobium douglasii*), larch (*A. laricis*), ponderosa pine (*A. campylopodum*), and lodgepole pine (*A. americanum*).

Western Dwarf Mistletoe

Western dwarf mistletoe (*Arceuthobium campylopodum*) on ponderosa pine does not occur throughout all the susceptible host type in the Blue and Wallowa Mountains, but is common on districts in the south portion of the Wallowa-Whitman NF, the Heppner and North Fork John Day Districts on the Umatilla NF, and all Districts on the Malheur NF. Incidental infection may occur on other districts. Highest incidence is on portions of the Baker and Unity Districts (WAW), and Bear Valley and Prairie City Districts (MAL). In the pine host type in the Blue Mountains, incidence is believed slightly lower than the Region-wide average reported by Bolsinger (1978) of 26 percent. Lehmkuhl *et al.* (1994) found a slight but insignificant increase in western dwarf mistletoe hazard for the Grande Ronde basin between historical (1938, 1948 or 1955), and current conditions (1987). This hazard rating is based on stand susceptibility and the actual levels of infection may be substantially different. Stand level evaluations indicate that western dwarf mistletoe has continued to intensify most noticeably on the dry pine plant community series sites; those sites that continue to maintain a pine understory with the absence of fire. Ponderosa pine series plant communities always are stocked with a high proportion of pine; thus, there is always a host component. This condition helps facilitate maximum spread of *A. campylopodum*. Fire once played the role in keeping western dwarf mistletoe in check, since infected trees are much more apt to be killed during fires due to persistent lower broomed limbs serving as fuel ladders (Fig. 22). Bark beetles may kill infected trees as a result of fire-induced stress adding to their already weakened condition. Damage can be high in these stands where mistletoe is present as well as those more mesic sites that are unable to regenerate pine due to grand fir or Douglas-fir encroachment and competition. Some of the warm/dry plant communities in the grand fir and Douglas-fir series have a major component of ponderosa pine only in early stages of succession. Historically, these stands had been maintained in pine-dominated conditions by frequent light ground fires. Theoretically, such a condition favored mistletoe proliferation by maintenance of a near-pure host type. Pine-dominated stands have diminished and stands of predominantly shade tolerant fir have replaced them on many sites in the Blue Mountains. There is actually a decrease in level of infection where firs have invaded pine sites since hosts are now a much lower proportion of the stand component. Unfortunately, such conditions are not encouraged in ecosystem management since shade tolerant grand fir and Douglas-fir are susceptible to a number of insects and diseases in such situations and losses are frequently catastrophic. Also, most recent and planned cultural activity strives to restore stands to within their natural range of variability (NRV), which usually includes more pine than currently present.

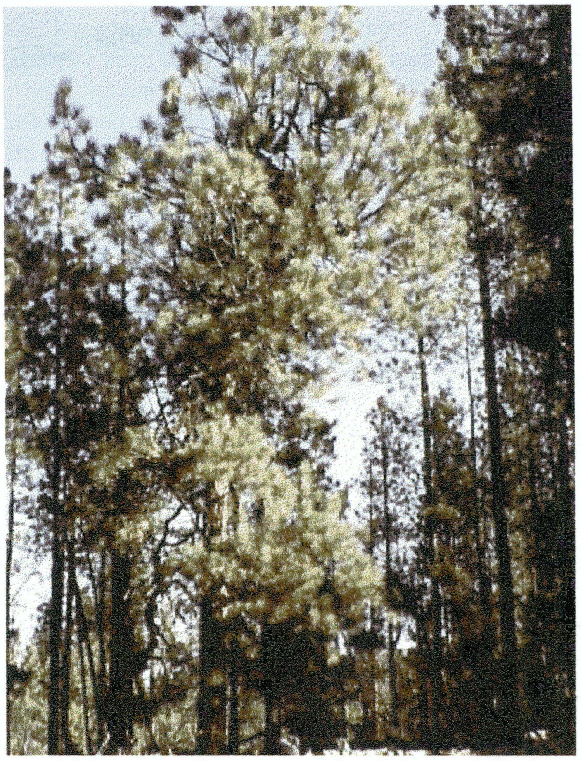


Figure 22. Ponderosa pine with large persistent brooms resulting from dwarf mistletoe infection.

In the absence of natural disturbance regimes, successful long-term management of ponderosa pine in stands affected by *A. campylopodum* requires an active program of stocking level control, sanitation, and cleaning, especially if unevenage management is directed. Direction to develop unevenage stand structure with multiple canopy layers will allow mistletoe levels to intensify in infected stands. Current management policy requires that large diameter trees be maintained in stands in most cases regardless of mistletoe infection and risk to developing understory. A recent management guide has been completed for western dwarf mistletoe that considers multiple resources (Schmitt 1996a).

The need to maintain an endemic level of brooming over the landscape for use by wildlife is a more visible concern now than it was five years ago. Some of the literature addressing this subject is fairly recent. Bennetts *et al.* (1991a) found a positive correlation between the intensity of dwarf mistletoe in ponderosa pine in central Colorado and both the number of species and the total number of birds. Average dwarf mistletoe rating (DMR) was by far the most significant factor affecting both total number of birds and diversity of bird species. Nests constructed and used by five species of birds were found in brooms of infected trees. Bennetts *et al.* (1991b) found the number of mule deer and elk pellets were higher in mistletoe-infected stands. Brooms caused by dwarf mistletoes are documented as preferred sites for nesting and hiding habitat for a variety of birds and small mammals. Bull *et al.* (1988) found that great gray owls built 20 percent of their stick nests in mistletoe brooms, most of which were in mistletoe-infected western larch but also included ponderosa pine. Severely dwarf mistletoe-infected, thus weakened pine, are more likely killed by western pine beetles. These standing snags provide prime cavity nesting sites and perches for raptors and other birds. When they topple they provide large woody material and associated habitat on the forest floor.

Leach (1956) reports on both volume of plant parts ingested and frequency of occurrence of *A. campylopodum* in the stomach contents of mule deer in the Great Basin of northern California. Porcupine are well documented in eating both aerial shoots of dwarf mistletoe and the bark and cambium of swollen infected branches. Mistletoe plants are apparently an important fall and winter food source (Lawrence 1957, Hooven 1971). A variety of mammals, including several species of squirrels and chipmunks, pine marten and porcupine have been reported to feed on mistletoe aerial shoots and/or use brooms for nesting or hiding cover (Spencer 1987). Blue grouse in the Blue Mountains are documented as ingesting dwarf mistletoe plants as part of their fall diet. Crawford *et al.* (1986) found mistletoe plant parts in the stomach contents of birds that were probably *A. laricis* (western larch) and *A. douglasii* (Douglas-fir).

Dwarf mistletoe and its effects are best managed within the context of historical occurrence and levels of intensity. Watershed-level landscapes that have been thoroughly sanitized of infections will not provide historical levels of wildlife benefits. Conversely, excessive levels of mistletoe will impact stand growth and limit the development of large diameter trees. Additionally, the risk of stand replacement fire is much greater in severely-infected stands and is a critical resource protection issue. Providing the benefits of endemic levels of infection in stands to various species of wildlife should be part of management direction in most situations. Reynolds *et al.* (1992) puts this in the proper context with recommendations for managing stands for the northern goshawk in the southwestern United States,

> "Dwarf mistletoes can alter the structure of forests by reducing growth and increasing tree mortality. Some of these changes, as well as the mistletoe plant itself, benefit wildlife (Bennetts 1991b). Over time, however, mistletoe related changes can be detrimental to some goshawk prey species. For example, ponderosa pine stands severely infected with southwestern dwarf mistletoe (*Arceuthobium vaginatum* subsp. *cryptopodum*) became stagnated and may not develop the young forest stage (VSS 3) or may revert, because of high mortality, to the grass/forb/shrub stage (VSS 1).
>
> Management recommendations for developing the desired forest conditions could include application of sanitation cuts and thinnings to reduce the detrimental effects of mistletoe in the post-fledging family areas and foraging areas."

Douglas-fir Dwarf Mistletoe

Douglas-fir dwarf mistletoe (*A. douglasii*) is found throughout most of its host type in the Blue Mountains. Certain plant communities are likely to have had a historically high rate of infection, and others are believed to have become severely infected in the last century. Of all the mistletoes in the Blue Mountains, *A. douglasii* is becoming the most damaging; spreading and intensifying on sites where it had never been a problem in the past. Based on an expansion of susceptible host type, Lehmkuhl *et al.* (1994) found a significant increase Douglas-fir dwarf mistletoe hazard for the Grande Ronde basin between historical (1938, 1948 or 1955), and current conditions (1987).

In the Douglas-fir plant community series and moist end of the pine series, Douglas-fir has always been a stand component. Douglas-fir in all communities that support early- to mid-seral components of Douglas-fir can have rather high levels of infection. Being most common in the CD series (Wicker and Leaphart 1974), *A. douglasii* occurs in all successional stages, but it tends to be most severe in later seral and climax vegetation. Dry Douglas-fir series communities such as Psme/Phma and Psme/Syor frequently have dramatically severe levels of dwarf mistletoe as a result of perpetual stocking of the host. Stocking has usually increased with progression of succession since fairly frequent intervals of underburning kept succession skewed toward its early stages. Suppression of fire has caused four (4) very crucial changes:

1. Douglas-fir stocking, especially in the understory, has proliferated on sites once kept primarily in pine stocking. Typical stands may have once had a dominant pine and minor fir overstory, and a lightly-stocked pine dominated understory. Most of these stands now are completely stocked with fir in the understory and have become heavily infected with dwarf mistletoe from overstory sources.

2. Douglas-fir is invading pine communities where it previously could not become established. Dwarf mistletoe is following the expansion of its host's range via tree-to-tree spread, and inadvertent spread by birds and possibly small mammals.

3. Stocking levels in all cases have increased dramatically. With increased stocking and associated abiotic stresses, dwarf mistletoe-infected trees are more likely to be killed by secondary or associated insects, such as the Douglas-fir beetle. These beetles can build to epidemic status in stressed trees. In the last several years we've identified high endemic beetle activity in the Starkey area, often on mistletoe-infected and spruce budworm-defoliated fir.

4. Mistletoe-infected firs usually have excellent fuel ladders such as dead needles and resin-soaked tissue in brooms that are frequently near the ground. Upon ignition, heavy stocking of these trees will easily carry the fire into the crowns including associated old remnant pine, creating a stand replacement event where underburns were once the norm.

These stand condition scenarios are very common and they alone account for one of the most common changes in Blue Mountains forested stand conditions in the last century. Historically light- to moderate-intensity fire tended to reduce the level of mistletoe in stands by removing a higher proportion of trees with heavy infection. Broken brooms around the bases of infected trees allowed hotter temperatures and higher flame length around these trees (Wicker and Leaphart 1974). Not only individual trees, but centers of severe and advanced mistletoe infestation were much more likely to crown during a burn because of low-hanging broomed branches that ignited (Fig. 23); eradicating those centers of heavy infection. Now, many thousands of acres on the Forest are susceptible to stand replacement fire where open, pine-dominated conditions once prevailed. Watershed and fisheries resources are at grave risk where large expanses of conflagration-susceptible stands occur.

Additional effects to dwarf mistletoe Infected fir includes reduction in growth rates, top-kill, and outright premature mortality. Mortality is most severe on poor sites, such as ridgetops with shallow soils. Trees of all

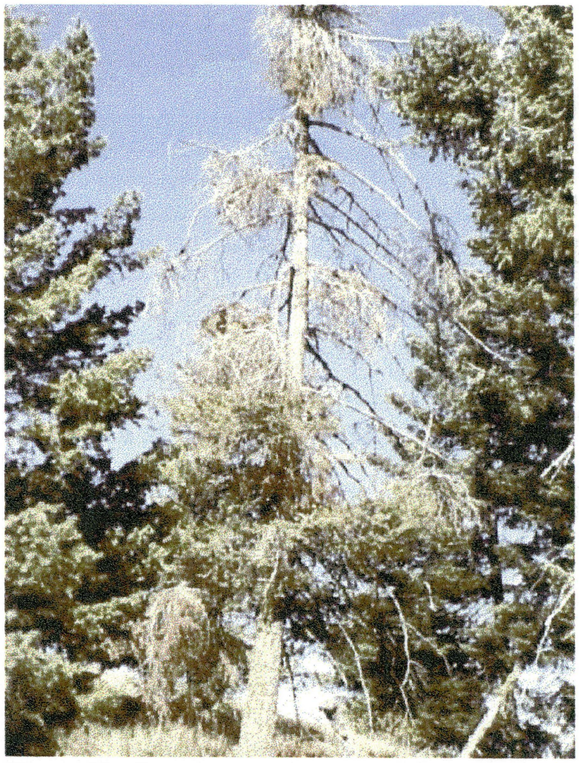


Figure 23. Douglas-fir severely infected with dwarf mistletoe.

ages are killed, depending upon rate of disease intensification and time infected.

Broomed fir provide for excellent habitat diversity. Several birds and small mammals are known to use broomed branches for hiding and nesting cover. Bull and Henjum (1990) reported that 20 percent of the great grey owls they studied used Douglas-fir dwarf mistletoe brooms as nesting platforms. In northeastern Oregon, Douglas-fir brooms are reported used by porcupines for winter protection from snow and wind (Smith 1982). Douglas-fir brooms are also commonly used by grouse for roosting cover (Martinka 1972; Stauffer and Peterson 1986; Weir 1916). In Arizona, Seversen (1986) reports that Douglas-fir dwarf mistletoe seeds make up 2 to 8 percent of the diet of the blue grouse (which also occur in the Blue Mountains).

Restoration of Douglas-fir dominated ecosystems presents significant challenges where there is an excess of Douglas-fir dwarf mistletoe infection. To effectively reduce mistletoe to historic levels, sanitation needs to be reasonably complete. Residual infected trees can be left for habitat reasons, but these trees should be left in groups rather than scattered as individual trees throughout the stand. Groups can be effectively isolated from the rest of the stand by maintaining a 30' horizontal distance buffer of non-hosts or unstocked area. Most of these groups should be on those microsites where Douglas-fir dwarf mistletoe was historically common, such as ridgetops and in draws. These sites are also most easily isolated. Many of these sites are rather xeric and have lost some of their pine component, either by bark beetles or by harvest.

Larch Dwarf Mistletoe

Larch dwarf mistletoe (*Arceuthobium laricis*) is found throughout most of the range of larch. Some occasional stands or large portions of stands are free of infection. This is largely the result of stand history; relatively recent hot stand replacement fires that removed mistletoe-infected, normally fire resistant residuals, can create these uninfected expanses. Over time, birds likely reintroduce infection into these areas protected from traditional tree to tree spread by inadvertently carrying viable mistletoe seeds.

Before suppression of wildfires, larch was a major early seral component in most mixed conifer mesic communities, including most of the cold high elevation subalpine fir communities, all the grand fir series sites, and the moist end of the Douglas-fir type. Given its very thick bark, those trees that matured survived periodic fire and some stand replacement fires. Following these disturbances, larch frequently regenerated very heavily. Overstory larch infected with mistletoe served as a source of infection to the developing understory. Mistletoe in larch works slowly and these infected residuals remained alive until they are a component of the overstory. Gradually, crowns deteriorate and no longer supported the weakened host. As the overstory died, they were replaced by understory larch already on site or seeded in on disturbed sites. Larch dwarf mistletoe seemed well adapted to the fire and successional ecology of these communities, and served as a creator of snags.

Distribution of larch dwarf mistletoe is believed similar to historic conditions. Lehmkuhl *et al.* (1994) found no change in larch dwarf mistletoe hazard for the Grande Ronde basin between historical (1938, 1948 or 1955), and current conditions (1987). Based on stand level evaluations, there has however, been a dramatic shift in structure of some stands with a component of larch. In certain portions of the Blue Mountains, larch regeneration is less than desirable. Either due to lack of disturbance or understory grand fir dominance, larch is not effectively becoming established. Overstory trees gradually lose their seed producing potential as their crowns deteriorate from the effects of brooming and breakage while at the same time the understory is stocked with mostly shade tolerant species and larch regeneration is substantially lower than historical levels. In some portions of the Blue Mountains, especially on the Wallowa Mountains side (eastern portion) of the LaGrande District (WAW), and the Walla Walla District (UMA), larch regeneration has been quite successful. Where regeneration is a problem and larch overstory trees are dying (usually by mistletoe infestation), loss of larch is a significant concern, as diversity diminishes and seed sources are lost, especially if we have large-scale hot fires that eliminate large larch residuals. Given the current level of fuel loading, this is much more likely to happen than any time in the past. Large old larch with stem decay and larch snags provide habitat for cavity nesting birds. Since larch is relatively tolerant of most root diseases, most of these snags remained standing for a relatively long time. Dwarf mistletoe brooms on larch are not as large or persist like those of Douglas-fir, but they can serve as perches or nesting platforms for birds and small mammals, rather than effective hiding or nesting habitat as with brooms on Douglas-fir.

Restoration of natural ecosystem conditions will call for restoring some pattern of early seral stages where they are lacking. Larch regeneration requires some significant level of created opening, either by timber removal or fire. Mistletoe infection can be expected to follow larch establishment in the stand, either by residual reinfection, spread from an adjacent stand, or avian spread.

Mistletoe should be kept to a low endemic level to minimize impacts resulting from slow tree growth and premature mortality. Due to the wide-spread nature of *A. laricis*, and the severe levels of infestation in many areas, keeping historical levels of infection within managed stands is not an issue at present. The removal or killing of most overstory residuals should follow establishment of regeneration in most cases. If larch dwarf mistletoe is believed under-represented over a large area such as a subwatershed (approximately 10 percent or less of the larch component is infected), it may be desirable to purposely leave infected trees during any regeneration harvest treatments. Since trees having a dwarf mistletoe rating (DMR) of 6 are likely to have the shortest survival time frame and spread less mistletoe than all but very lightly-infected trees, they may be preferable to leave since they will also serve as replacement snags. Infected trees with DMR of 3,4 or 5 that are left will survive longer and result in more spread to developing understory. Spacing larch that become established in overstocked conditions will mostly eliminate mistletoe growth-reducing effects by allowing trees to grow in height faster than the upward extent of infection. Keeping the brooming in the lower portion of the crown will allow trees to function near-normal in terms of growth. Differentiation in use of brooms by wildlife at different heights of the tree is not yet known.

Lodgepole Pine Dwarf Mistletoe

Lodgepole dwarf mistletoe is scattered throughout its host type, but does not reach the intensity found in the Central Oregon Plateau. Pure stands of lodgepole in lodgepole plant communities are most apt to develop and maintain the highest rates of infection. This is due to a perpetual near-pure component of host stocking on the site through the historical cycle of regeneration-maturation-beetle kill and large-scale stand replacement fire. A few scattered infected individuals that survive the beetles and fire will serve to spread infection throughout the stand for years following establishment of regeneration. Following the 1970's mountain pine beetle epidemic in the Blue Mountains, many thousands of acres of lodgepole stands were salvaged and some of the mistletoe-infected residuals surviving were removed or girdled, although infection was retained in most cases as scattered residuals or infected understory. Incidence of infections has been reduced from pre-mountain pine beetle epidemic levels, but not to the level that would have occurred with a fire. In their analysis, Lehmkuhl *et al.* (1994) found a slight but insignificant increase in lodgepole pine dwarf mistletoe hazard for the Grande Ronde basin between historical (1938, 1948 or 1955), and current conditions (1987). These results are believed to deviate substantially from actual changes in levels of lodgepole pine dwarf mistletoe infestation in the Blue Mountains during that time frame. Suppression of fire has allowed development of layered canopies as well as the carryover of mistletoe infection from earlier generations of trees that would normally have burned (Hessburg *et al.* 1994).

Lodgepole pine should be managed in evenage structure to emulate historical landscape patterns. Removing most or all sources of infection prior to establishing new stands will reduce the potential for mistletoe infection to become severe.

ROOT DISEASES

There are several major root diseases that affect stands in the Blue Mountains. Some of these are very common and affect stand structure. Another may be of concern only in a few specific areas. Lehmkuhl *et al.* (1994) found an insignificant decrease in root disease hazard for the Grande Ronde basin between historical (1938, 1948 or 1955), and current conditions (1987). This risk assessment differs from stand level analysis which indicates that incidence of mixed conifer root diseases (S-Type annosus root disease, laminated root rot, and Armillaria root disease) have increased throughout the Blue Mountains as a result of proliferation of host type and increases in certain types of stand disturbance. However, areas having had stand replacement fires and regeneration harvest have reduced hazard. Root diseases contribute to down woody material and create structural diversity as a result of mortality pockets. Most root disease-killed snags are short-lived since they topple prematurely due to decay of the root system.

Annosus Root Disease

In the Blue Mountains there are two different strains of *Heterobasidion annosum*, both of which cause annosus root disease; one which infects pine (P-Type), and the other true firs (S-Type).

Annosus root disease in pine is found mainly in the dry pine plant community series stands, most often on fairly poor sites. Annosus spreads by airborne spores produced from conks of the fungus that fruit in old stumps and around the bases of infected pine. Spores infect freshly-cut stumps or wounds, and the developing fungus colonizes the woody tissue and roots over several years. Pine growing near these sources of infection may eventually become infected as roots contact roots of infected stumps (usually at least 15 years since initial adjacent stump infection).

Infected pine sites in the Blue Mountains tend to be most prevalent on dryer ponderosa pine community sites. The southern portion of the Malheur NF has a relatively high incidence of infection. Sites on the North Fork John Day and Heppner Districts (UMA) are also fairly common. Because of the history of selective harvesting of pine in the Blue Mountains dates to the early part of the century, infection potential has likely already been fully expressed and P-Type annosus is not expected to increase in severity or incidence and is more likely to decrease in the future with the reduced harvest of large pine. S-Type annosus continues to increase in incidence and severity, resulting in root disease-caused decay and mortality to true firs.

Annosus in grand fir is similar in biology and spread. Grand firs near large fir stumps are at risk. Incidence of grand fir stump infection is very high; averaging at least 90 percent (Filip *et al.* 1992). Infection of adjacent fir occurs across all sites where fir is a component. Not all infected stumps result in root disease centers, however the occurrence of this disease in fir is rapidly increasing and becoming visible, especially on sites with several entries. Most all grand fir sites on the Forest with some early fir removals will have some level of this root disease. Fir harvesting, or inclusion in the sale volume only became common in the late 1960's. For that reason, annosus disease in fir stands is still appearing and already established centers are expanding. Stump treatment with borax is recommended wherever fir will be managed in the future (two products are currently registered and available: Sporax® and Tim-Bor®). Stump treatment of large fir stumps (>14"), has been Forest policy where fir will be managed in the future. These borate compounds contain boron as the active ingredient. Boron is a naturally occurring element and poses no risks to the ecosystem when used at recommended application rates. Currently, about 4 percent of the fir stocking on the Forest is affected with annosus (Schmitt *et al* 1991). These include the wet, mesic fir communities, and others where resource values require managing this species outside of its natural range of variability. Some recent concerns over the safety to applicators and also insect populations and wild and domestic ungulates were addressed in a Regional Borax Background Document (FID 1994).

A joint Region 5 and 6 annosus root disease information publication is being completed that compiles the pertinent information for this disease in the West (Schmitt *et al.* in review).

Armillaria Root Disease

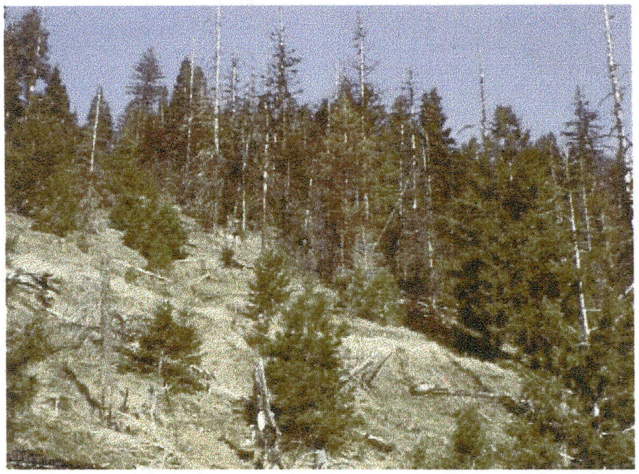


Figure 24. Armillaria root disease center in a mixed conifer stand. This is part of the several thousand acre root disease complex between Thirsty Gulch and Reynolds and Clear Creeks on the Wallowa-Whitman and Malheur National Forests.

Armillaria root disease, caused by *Armillaria ostoyae*, is the most common, widespread, and damaging root disease in the Blue Mountains. It is found on a variety of sites from dry pine communities to mesic spruce-subalpine fir stands. This native disease has a wide host range and is most severe on sites dominated by grand fir. Stands may have scattered single tree infections or large dramatic root disease centers (Fig. 24). All Districts in the Blue Mountains have this root disease and most have examples of large active root disease centers. An estimated 2 to 3 percent of trees in grand fir-dominated stand types are currently infected or have been killed by *Armillaria*. Douglas-fir and pine communities have less than 2 percent, and larch, less than 1 percent of their trees infected. A very large Armillaria complex extends from the Thirsty Creek drainage on the Wallowa-Whitman NF over the divide into the Reynolds Creek and Clear Creek drainages on the Malheur NF. This is likely the most virulent and large-scale Armillaria hotspot in the Blue Mountains. The Hoodoo Ridge area on the Walla Walla District also has a relatively active Armillaria root disease complex. This particular area is largely in unmanaged stands. Scattered smaller and perhaps less virulent disease centers occur throughout the mixed conifer type in the Blue Mountains, and examples can be found on all Districts in the region.

Armillaria was believed to always have been an endemic stand inhabitant, but several factors are causing it to become increasingly prevalent and severe.

1. Dramatic increases in primary host stocking (grand fir, Douglas-fir) on sites historically occupied by less susceptible conifers (pines, larch).

2. Exclusion of fire is allowing a gradual change in soil chemistry believed to increase virulence and activity of *Armillaria*.

3. Soil damage, compaction, and associated residual conifer damage is at lease partially responsible for some of the increase in *Armillaria* virulence that have occurred in recent years. Cat-yarding in repeated partial cut entries, especially during the wet season, is the main culprit. Attempts to practice unevenage management in mixed conifer stands will likely exasperate Armillaria virulence.

Research is needed to determine the best management practices to manage existing *Armillaria* root diseased areas and to prevent areas of infestation from developing.

Laminated Root Rot

Laminated root rot (*Phellinus weirii*) is not found in many areas of the Blue Mountains in abundance, but there are several areas with relatively high incidence. The La Grande RD (Wallowa-Whitman NF), especially on Mt.

Emily, has the highest level of infected sites on the Wallowa-Whitman. Smaller areas in Ladd Canyon and near Mt. Harris, as well, and the Wallowa Valley and Baker Districts also have confirmed infected sites on the Wallowa-Whitman NF. The southern portion of the Walla Walla District and the Tupper Creek and Madison Butte areas on the Heppner District (UMA), have substantial laminated root disease. Long Creek District on the Malheur NF has confirmed areas of infection in the Fox Creek and the ridge between Fox and Long Creek. Root diseased sites will contain numerous dead and down trees. Depending upon the size of the tree when infected and the time since infection, either mortality, butt rot, or growth loss may result.

Laminated root rot seldom spreads via spores, although that mechanism is responsible for very infrequent long-distance spread. Most spread is on already infected sites where root contacts between hosts and host regeneration tends to allow for perpetual host infestation. Stand conditions that allow maximum spread are late seral species dominance and lack of early seral species. Thus, fir dominance on pine and larch sites will allow for this pathogen to increase in disease virulence with radial spread at rates of 1 to 2 feet per year. Current laminated root rot occurrence is believed nearly identical to historical distribution although disease activity has likely increased with higher proportions of hosts.

Blackstain Root Disease

Blackstain root disease (*Leptographium wageneri*) was recognized several years ago in the southern portion of the Malheur NF as a major cause of mortality on mostly pole-to small sawlog-size ponderosa pine. Previously, these disease pockets were attributed solely to bark beetles, which are usually also present. Blackstain has been found on Starr Ridge and further south, becoming increasingly more common on the south portion of the Burns District, east of Highway 395. A relatively minor amount of infection was found on the Heppner and Pomeroy Districts (UMA). Blackstain in pine causes pockets of mortality that spread both via insect vectors (root-feeding beetles and weevils) and across root to root contacts. PNW Research Plant Pathologist Walt Thies and Research Entomologist Chris Niwa, are investigating several aspects of epidemiology and vector biology. Determining the effects of periodic light ground fires on the vectors and the resultant disease activity is a primary research need.

While several obviously older long-established centers are common, we are especially concerned with the prevalence of young, recently-visible, 1 to 3 tree mortality groups. These are considered satellite centers, having spread via insects some distance from older infected trees. We expect most of these to continue to increase in size and probably again multiply. Stand disturbance, some required to reduce overstocking, is known to exacerbate blackstain spread. We also believe that the change in ecological processes (removal of periodic fire) may be contributing to disease virulence. While the Burns District is mapping occurrence of blackstain, we don't know total acreage infected, but are sure that the infected sites and total area are steadily increasing, and will continue to increase given current stand conditions.

Other Root Diseases

There are other root diseases that can be found at low incidence over wide areas; others may only affect trees on certain sites. The following are two of the more common of these root diseases.

Schweinitzii root and butt rot (*Phaeolus schweinitzii*) is quite common in Douglas-fir and larch. Most other conifers are affected, but at much lower levels. This disease is found in most older stands and usually acts as a weak pathogen, infecting trees and slowly causing decay in the lower butt. Incidence is believed to be decreasing, largely due to losses of many older Douglas-fir and larch because of other factors including bark beetles and dwarf mistletoes.

Tomentosus root and butt rot (*Inonotus tomentosus*) is most common in stands with spruce. Almost all spruce sites have a moderate to high incidence of this pathogen. Mature trees will have several feet of decay in the lower bole and very frequently these trees fail or break in the lower butt because of advanced decay. Older spruces have higher incidence of disease and higher levels of decay. Since most older Blue Mountain stands of spruce have succumbed to spruce beetles in the last 12 years, tomentosus decay levels have plummeted, but will slowly build along with the developing maturity of spruce stocking.

STEM DECAYS

Indian Paint Fungus

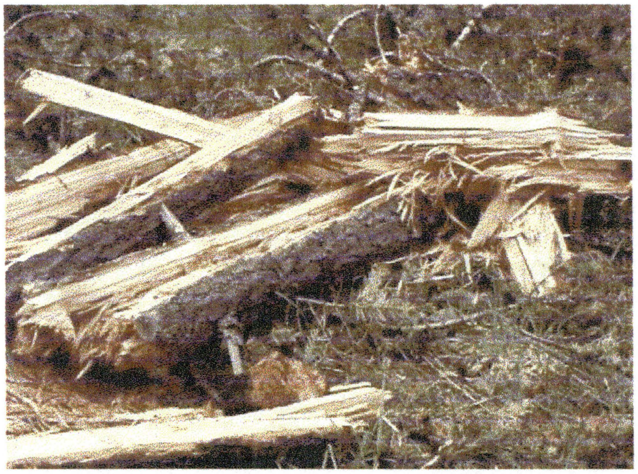


Figure 25. Indian paint fungus decay caused this grand fir to break mid-bole.

Indian paint fungus (*Echinodontium tinctorium*) causes internal heart decay of grand fir boles. Advanced stages of decay will usually extend from the butt to the upper stem, especially on moist sites and on older trees that have multiple infections. Similar sites with stands of older trees may have very high incidence of decay; frequently more than 80 percent decay, in terms of total fir volume (Fig. 25).

Incidence of decay is ever-increasing with the expanding prevalence of grand fir stocking on the Forest. Highest incidence is on most mesic sites where true firs are a native component. Pine sites also have Indian paint decay in the invading grand fir, but at much lower levels than on mesic sites. Highest incidence of this decay is in trees suppressed for five or more decades before release. Disturbed sites, especially where plenty of wounding occurred during selective harvest entries, typify sites prone to high levels of decay. Since these site and stand factors are contributing to ever increased hazard levels, we can expect the level of this specific decay to continue to increase. Our observations show that incidence of decay in fir currently is about 5 percent in pine/Douglas-fir dominated communities, increasing to 10 percent in mesic mixed conifer stands. Direction to practice unevenage management in mixed conifer stands, retain fir advance regeneration, and maintain trees to older ages will increase the amount of Indian paint fungus decay.

Grand fir with extensive decay, especially larger trees, provide important habitat for wildlife. Such trees help contribute to late and old forest character. Cavity excavating birds and those birds (eg. Vaux's Swift) and animals the use already created cavities are at least partially dependent upon grand fir with stem decay (Bull and Cooper 1991). Trees that break high in the bole can be used for a nest site for certain birds such as great grey owls (Bull and Henjum 1990). Black bear will sometimes use very large trees with decay as den sites (Akenson and Henjum 1994).

RUSTS

White Pine Blister Rust

White pine blister rust (*Cronartium ribicola*) is an introduced disease of 5-needle pines. In the Blue Mountains, western white pine and white bark pine are infected. Blister rust causes cankers to develop that girdle branches and the bole resulting in dead branches, dead tops, and very frequently, tree mortality. Western white pine stocking in the Blue Mountains has been reduced from scattered low historical levels. This is the result of selective removals in harvesting, mountain pine beetles, blister rust-caused mortality, and poor regeneration rates because of reduced fire occurrence. A review of the blister rust situation in the Blue Mountains in 1993 showed the incidence of infection in western white pine increased on a south-north gradient. Stands near Dixie Summit on the Malheur have a relatively low level of infection. In the northern part of the Blue Mountains, white pine becomes more common, as does the level and mortality caused by blister rust. Selection of select pine genotypes, breeding and propagation of resistant trees at Dorena Seed Orchard, is planned to restore pine stocking to historical levels in the Blue Mountains.

A more common host with associated high levels of infection is white bark pine, a high elevation species that is restricted to near-timberline sites in the Blue Mountains. Blister rust infection is known to be rather severe where air currents carry basidiospores from infected current (*Ribes* spp.) shrubs from down-slope positions such as on the divide between Anthony Lake and Crawfish Lake.

HARDWOOD DISEASES

A guide to insects and diseases of Blue Mountains wetland hardwoods has recently been completed and distributed (Schmitt 1996b). While hardwoods are an important community component on usually wet sites, comparatively little attention has been directed to this resource until recently. Hardwoods have there own insects and diseases which cause a variety of detrimental effects but also help create wildlife habitat. An example is white trunk rot of aspen that prepares trees for use by cavity excavating birds and their successors (Fig. 26). Restoration of declining aspen clones is a management priority throughout the Blue Mountains. While insect and diseases are principle causes of decline in mature trees, site conditions and grazing pressures have retarded success of seedling establishment.

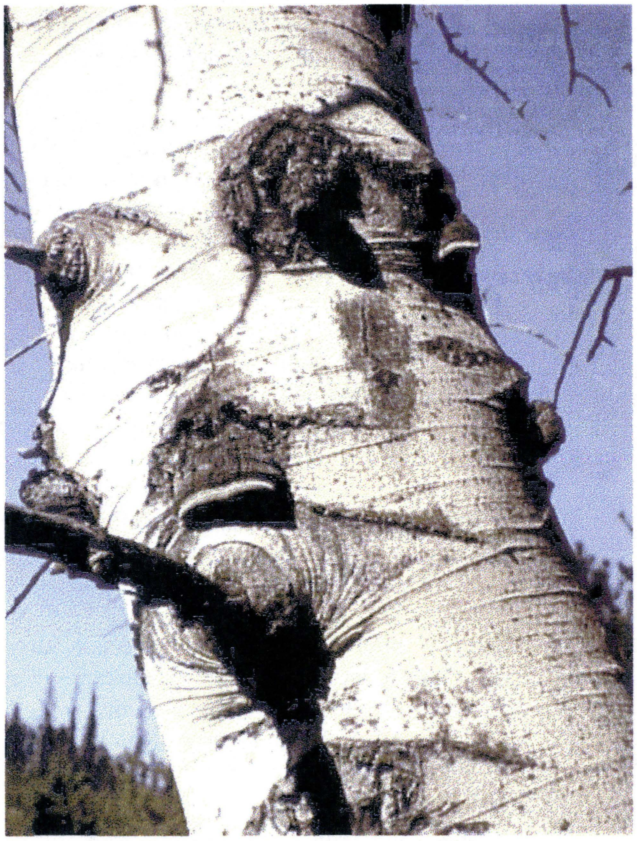


Figure. 26 This aspen has conks of the fungus that causes white trunk rot. While the rind of this tree is sound, there is extensive heart rot throughout the stem.

ACKNOWLEDGEMENTS

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